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**UNOSAT**

# UNOSAT analysis of destruction and other developments in Rakhine State, Myanmar

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## Introduction

The United Nations Institute for Training and Research - Operational Satellite Applications Program (UNITAR - UNOSAT) conducted satellite imagery analyses at the request of the Independent International Fact-Finding Mission on Myanmar. UNOSAT sought to produce information and evidence related to widespread destruction in Buthidaung, Maungdaw, and Rathedaung Townships of Rakhine state in Myanmar in late August 2017 and subsequent months using high-resolution optical satellite imagery and fire detection data. Specifically, at the request of the Independent International Fact-Finding Mission on Myanmar, UNOSAT sought to:

- best understand the temporal aspects of the conflict in Rakhine by identifying which settlements had experienced damage and destruction, and when that destruction happened with as much specificity as feasible;
- assess post-conflict debris clearance and construction activities in the affected townships, and;
- review data on fires detected by satellites during the period in question.

This report contains an overview of the data sources, methods, and results of the analyses.

## Data and Methods

To document evidence of destruction, debris clearance, and construction activities in the affected townships of Rakhine state UNOSAT utilized high-resolution satellite imagery from a commercial source as well as fire detection data from US Government satellites. Data describing the location of settlements in Myanmar was also used. The satellite images, fire detection data, and settlement locations were reviewed using Geographic Information System (GIS) software by UNOSAT analysts and results were compiled by the project focal point. The results also informed a statistical analysis to estimate the number of destroyed structures across the affected townships. Further information on these data sources and analysis steps are detailed below.

### Satellite Images and Processing

The satellite images of northern Rakhine that were used in the analysis are portions of images acquired by multiple satellites on multiple dates spanning 31 August 2017 to 18 March 2018. Latest imagery selected for the analysis was collected on March 2018 since it was the best available cloud free imagery covering the whole area. Some additional images have been collected after March 2018, though the presence of cloud cover doesn't make them suitable for a comprehensive analysis across the three affected townships. In addition, the latest cloud free available images from prior to August 2017 were also used for reference. The satellites used are commercial satellites operated by a private company, DigitalGlobe<sup>1</sup>, and collect images at up to 31 centimeter resolution. Images obtained by these satellites were not collected for all the area of interest every day. Rather, they were collected somewhat sporadically and on some days almost all of Rakhine may be covered by an image, and on other days a small portion may be imaged, and on most days no imagery was collected in Rakhine. UNOSAT staff searched all available imagery from DigitalGlobe and selected the best available cloud free imagery over all or most of the area of interest and collected approximately every 3 weeks. Due to the presence of clouds and less frequent collections, the area located in the northwestern end of Northern Rakhine was assessed with only monthly or bimonthly imagery and the latest imagery analyzed was collected in February 2018. Selected images were downloaded to the UNOSAT computer network and then processed as needed and loaded into the ArcMap GIS software for analysis.

<sup>1</sup> See: <https://www.digitalglobe.com/>

## Satellite Image Analysis

Analysis of the satellite imagery was done by UNOSAT analysts using GIS software. As the analyzed area is relatively large, and imagery spanning multiple dates needed to be analyzed, specific areas of the affected townships were distributed between multiple UNOSAT analysts. Each analyst visually reviewed the satellite images in their region in progressive fashion from north to south and west to east so that every visible detail of the satellite images was analyzed. In this way all the images were visually compared, spanning the period covered in the pre-conflict imagery through to 18 March 2018, and visible destruction, debris clearance, and construction were identified. In satellite imagery the type of destruction occurred is usually readily visible, especially if imaged soon after it occurs. However, it is unlikely that all damage is actually visible in satellite imagery due to its inherent limitations, for example if damaged structures are under tree cover, if a shadow or haze obscures the area, or if the damage is somewhat minor or affects parts of the structures that are not visible from above. A visual example of two different types of damage visible in imagery, caused by burning and by demolition, is presented in Figures 1 and 2. Similarly, debris clearance and construction activities are readily visible, though again with similar limitations as with damage assessment, and are demonstrated in Figures 3 and 4.

During their analysis UNOSAT staff created vector data that represented visible destruction as it appeared on the various dates analyzed, and also similarly denoted debris clearance and construction activities in the analyzed area. When analysts finished their assigned region their results were then reviewed by the project focal point for quality control and harmonization purposes.

**Figure 1: Example of destruction caused by fire visible in satellite imagery**



These images show a portion of the village of Thauk Khu Lar (Song Khu Lar), Maungdaw Township, as of 25 September 2017 (left), with numerous building rooftops visible, varying in colour and size. By 1 October 2017 (right), all visible structures except for one located on the northeast have been completely destroyed. The presence of scorching and darkened soils in the areas where the structures used to be and the surrounding burned vegetation indicate that the destruction was caused by fire. Imagery courtesy of DigitalGlobe.

Figure 2: Example of destruction caused by demolition visible in satellite imagery



These images show a portion of the village of Maung Hla Ma, Buthidaung Township, as of 9 January 2018 (left), with numerous building rooftops visible. By 13 February 2018 (right), most of the visible structures have been completely destroyed. The presence of light colour debris and the absence of burned vegetation indicates that the cause of the damage did not involve fire and was more likely caused by some type of demolition. Imagery courtesy of DigitalGlobe

Figure 3: Example of debris clearing in satellite imagery



These images show a portion of the town of Doe Tan, Maungdaw Township, as of 9 January 2018 (left), with areas with signs of scorching and presence of debris. By 13 February 2018 (right), all visible debris has disappeared together with the surrounding vegetation indicating that the terrain has been cleared. Marks and tracks consistent with heavy equipment are also visible. Imagery courtesy of DigitalGlobe.

Figure 4: Example of construction in satellite imagery



These images show a portion of the town of Kan Kya (South), Maungdaw Township, as of 9 January 2018 (left), where there are visible signs of recent terrain clearance. By 27 February 2018 (right), at least 12 new buildings have been erected at the site. The presence of a defensive perimeter fence around the new buildings indicates that it is possibly a new security installation. Imagery courtesy of DigitalGlobe.

### Fire Detection Data

UNOSAT also analyzed fire detection data produced by the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor carried on-board two satellites operated by the US National Aeronautics and Space Administration (NASA), launched in 1999 and 2002 respectively. The MODIS sensors acquire images of the surface of the earth at least once every two days and up to four times per day, and fire detections are derived from these images using an algorithm developed by NASA and used for scientific research, firefighting, and other purposes around the world. UNOSAT downloaded the complete record of MODIS fire detections for Rakhine state spanning 1 August 2001 through 1 May 2018 from the Fire Information for Resource Management System (FIRMS) at the NASA Earth Observing System Data and Information System<sup>2</sup>.

Precisely which fires the MODIS sensors detect varies and such fires can generally be considered relatively large, for example involving 20-50 square meters of ground area or larger, and also must be thermally active at the time of the satellite overpass. Other factors are also important, such as presence of cloud cover and the timing of gaps in the coverage of the MODIS sensor. MODIS is unlikely to detect individual structure fires, but multiple adjacent structure fires are well within its detection capabilities. A full discussion of MODIS fire detection characteristics and capabilities is beyond the scope of this document, though it should be noted that UNOSAT regularly uses fire detection data in its operations.

A separate satellite-based fire detection system also exists, produced from the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor flown on the Suomi NPP operated by the US National Oceanic and Atmospheric Administration. VIIRS collects more detailed data than MODIS and thus is able to detect smaller fires, but has only delivered fire detection data since 20 January 2012. UNOSAT also downloaded all the VIIRS data for the affected townships from the NASA FIRMS website.

<sup>2</sup> See: <https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms>

## Fire Detection Data Analysis

Fire data analysis first sought to determine how common fire detections are in the affected townships. Fire is used in Myanmar and around the world for land-clearing, agricultural purposes, and other uses, and UNOSAT assessed the seasonal fire detection pattern in Rakhine state to determine when such use might occur. This assessment indicated that since year 2000 fire detections usually occur in Rakhine state every year during roughly the February through April time period. As the violence in Rakhine reportedly started in August, UNOSAT assessed yearly fire detections in the months of August through November, thus excluding the period of 'normal' agricultural burning. To analyse the fire detections during these months, UNOSAT used its GIS software to summarize all fire detections occurring during the months of August through November in the affected townships spanning the years 2001 through 2017 for MODIS data and from 2012 through 2017 for VIIRS data.

## Settlement Locations

In order to help quantify the results of the satellite imagery analysis, UNOSAT also used data which describes the location of 'official' towns. This data is produced for all of Myanmar by the Myanmar Information Management Unit (MIMU)<sup>3</sup>. MIMU is a service to the UN Country Team and Humanitarian Country Team, under the management of the UN Resident and Humanitarian Coordinator. The list of settlements and their locations is based on information collected from a variety of sources, including a Government gazette and humanitarian and development organizations. Notably, MIMU data describes settlements as a single point, and in reality settlements can be quite dispersed and extend relatively far from that identified point, therefore the list of settlements is an approximation. Regardless, MIMU data indicates that there are 993 settlements in the affected townships, 371 in Buthidaung, 399 in Maungdaw and 223 in Rathedaung.

As there are known problems in the MIMU settlement data, such as missing settlements (i.e. those in hard to reach areas, or settlements simply overlooked), and settlements which have been moved in recent years, UNOSAT attempted to compensate for those gaps. Specifically UNOSAT performed a satellite imagery based analysis identifying damaged or destroyed settlements in areas not apparently covered in the MIMU list. The criteria used for the analysis was based on basic geographical features: for instance, any group of houses located more than 1 km away from other settlements in the MIMU list was considered as an additional settlement. Also, any group of houses separated from other settlements in the MIMU list by a geographical barrier, such as a river, were also considered as an additional settlement.

## Estimation of the destroyed structures

An estimation of the destroyed structures in the affected townships between 25 August 2017 and 18 March 2018 was derived from UNOSAT damage assessment using a statistical predictive analytics based on a simple linear regression. A sampling of representative areas was identified and a structure count was performed in the selected areas. The sample dataset created was then used to estimate the number of structures destroyed within the identified damaged areas across the three townships. The accuracy of the estimation was assessed using an independent sampling dataset as a validation.

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<sup>3</sup> See: <http://themimu.info/>, and note the specific data used is at <http://themimu.info/place-codes>.

## Results

Using the data and methods described above, UNOSAT was able to concisely determine the presence and patterns of destruction, debris clearance, and reconstruction as they developed in Buthidaung, Maungdaw and Rathedaung Townships of Rakhine State between 25 August 2017 and 18 March 2018. In addition, fire detection data analysis clearly shows a unique pattern of fires occurring in the affected townships during the reported period of violence. These results are elaborated below.

### Destruction Visible in Satellite Imagery

UNOSAT satellite image-based analysis revealed widespread destruction in the Maungdaw, Buthidaung and Rathedaung Townships. In order to quantify the extent of the damage, UNOSAT analysis was combined with the MIMU settlement list that is used as a reference. Analysis indicated that a total of **392 settlements were affected between 25 August 2017 and 18 March 2018**, which include 96 in Buthidaung, 277 in Maungdaw, and 19 in Rathedaung Townships (table 1). Of these 392 settlements, 214 were partially destroyed, while 178 were completely or almost completely (more than 90%) destroyed (table 2). Moreover, UNOSAT performed an estimation of the number of destroyed structures in the 392 affected settlements, using a statistical approach and results revealed that approximately **37,700 structures** were destroyed in the affected townships between 25 August 2017 and 18 March 2018 (table 1). UNOSAT also conducted a validation assessment that indicates that the number of structures is likely underestimated by a 10%.

**Table 1. Number of affected villages and towns and estimated destroyed structures between 25 August 2017 and 18 March 2018**

Township	Total number of villages and towns (MIMU list)	Number of affected villages and towns (MIMU list)	% of villages affected	Estimated destroyed structures
Buthidaung	371	96	25	3,500
Maungdaw	399	277	70	31,300
Rathedaung	223	19	8	2,900
<b>Total</b>	<b>993</b>	<b>392</b>	<b>40</b>	<b>37,700</b>

**Table 2. Number of affected villages and towns grouped by the level of destruction occurred between 25 August 2017 and 18 March 2018.**

Level of destruction	Buthidaung	Maungdaw	Rathedaung	Total
Less than 50 % destroyed	71	59	4	134
More than 50% destroyed	18	62	-	80
Completely destroyed	7	156	15	178

The majority of the detected damage, approximately 80%, was already visible as of 16 September 2017 when approximately 30,800 estimated structures were visibly destroyed in 279 different settlements, 31 in Buthidaung, 234 in Maungdaw and 14 in Rathedaung Townships. Due to the presence of extensive cloud cover in the imagery collected on 16 September, the damage occurred as of this date is very likely underestimated. Through the analysis of subsequent cloud free images collected on those areas on several dates between the end of September and early October, UNOSAT was able to identify approximately 1,700<sup>4</sup> additional structures and 10 additional villages that were damaged sometime between 25 August and early October, but due to the presence of clouds in some of the images, it is not possible to determine accurately when this new damage occurred, i.e., before or after 16 September 2017. Nonetheless, given the pattern of the damage and the presence of fire detections on those areas, it is likely that a great part of it might have happened before 16 September 2017. On the other hand, UNOSAT analysis also revealed that new damage still occurred in multiple areas after 16 September 2017 and approximately 2,200 structures were destroyed between 16 September and 11 October in 96 different settlements, 24 of which were newly targeted settlements and were intact as of 16 September 2017.

Destruction continued in the weeks and months between early October 2017 and March 2018, when the latest analyzed image was collected. The intervening damage affected settlements that were previously damaged but also expanded to new areas, affecting previously intact settlements. During the first weeks of violence, between 25 August and 11 October 2017, analysis indicated that a total of 313 settlements were destroyed or partially destroyed and furthermore, between 11 October 2017 and 9 January 2018 a total of 45 previously intact villages were affected by new damage. Between 9 January and 18 March 2018, a total of further 34 previously intact villages were also damaged.

In the first weeks of the conflict, satellite imagery indicated that the type of damage observed was in general caused by fire, as signs of burning and scorching and occasionally smoke were visible. This damage usually affected entire settlements or large groups of structures at once. On the contrary, the pattern of destruction in the later months, mostly after November, was often progressive, with single buildings or small groups of buildings destroyed every few weeks in many different settlements, and caused either by fire or by demolition. Therefore some villages were not quickly destroyed, but rather slowly demolished over a span of weeks or months. Analysis revealed that while a total of 139 villages were destroyed during a single period of time, a total of 253 were targeted in several different periods of time.

After the initial wave of destruction occurring between 25 August and 16 September 2017 when 279 settlements were destroyed or partially destroyed, subsequent peaks of widespread destruction occurred between middle December 2017 and March 2018. During these peaks, many different settlement were affected by damage during the same timeframe. For instance, between middle December 2017 and early January 2018, around 200 structures were destroyed in 82 different settlements (31 in Buthidaung, 49 in Maungdaw and 2 in Rathedaung Townships) and while some of this settlements were previously intact, many others were being targeted again after suffering damage in the past weeks/months. Between early January and middle February 2018, around 1,000 structures were destroyed in 134 affected settlements (51 in Buthidaung, 79 in Maungdaw and 4 in Rathedaung Townships) both in previously damaged and also intact settlements. The same pattern occurred in the latest analysed images, collected in March 2018, when approximately 300 structures were additionally destroyed within 93 affected settlements (48 in Buthidaung, 43 in Maungdaw and 2 in Rathedaung Townships) both previously damaged settlements and intact ones.

<sup>4</sup> These 1,700 structure were distributed in 10 previously intact villages but also affecting 38 other villages that were already visibly damaged as of 16 September 2017 and are therefore included in the 279 initially damaged settlements



Considering the settlements which may be missing from the MIMU list, UNOSAT located an additional 35 settlements that were destroyed or partially destroyed in Northern Rakhine between 25 August 2017 and 18 March 2018, 18 in Buthidaung Township and 17 in Maungdaw Township.

The spatial distribution of the damage also varied across the months. Damage occurring before 16 September 2017 was more concentrated in Maungdaw Township, where it extended across the entire township, but also to a minor extent in Buthidaung and Rathedaung Townships. On the contrary, the damage occurring after 16 September is scattered across the majority of the territory of Maungdaw and Buthidaung Townships.

In southern Maungdaw Township, mostly in the village tracts of Kyauk Pan Du, Thin Baw Kwe, Inn Din and Tha Win Chaung, and in Rathedaung Township only some limited destruction was observed after 11 October 2017.

In central Maungdaw Township, analysis revealed widespread damage occurring in the months of December 2017 and January, February and March 2018. These new damaged structures were mostly located in the village tracts between Maungdaw town and Myin Hlut village tract and affect mostly intact structures that remained in previously damaged settlements.

In northern Maungdaw Township, analysis revealed a continued pattern of progressive destruction during the months of October, November and December 2017. Additional destruction occurred during the months of January and February 2018, especially concentrated in the village tracts of Aung Zan, Hlaing Thi and Taung Pyo Let Yar.

In central Buthidaung Township, some damage was observed during the month of September 2017, mostly concentrated in the village tracts of Zee Hton, Yin Ma Kyaung Taung, Nga Yant Chaung (a) Taung Bazar, Thin Ga Net, Mee Chaung Zay and Dar Paing Sa Yar, and also to the south in Gu Dar Pyin village tract. Continued sustained damage is observed afterwards across northern Buthidaung Township between November 2017 and March 2018.

UNOSAT analysis also showed that in several village tracts across Northern Rakhine, there is a repeated pattern in the damage where most of the settlements have been destroyed except for some villages that have a more structured design and different appearance of their buildings. Imagery shows the presence of pagodas in many of these villages which indicates the possible presence of Rakhine ethnic groups in those areas. This pattern is observed in the village tracts of Kha Maung Seik, Laung Don, Inn Din, Nyaung Chaung, (Du) Chee Yar Tan, Gaw Du Thar Ra (Ywar Thit Kay), War Cha, Ta Man Thar, Zaw Ma Tet, Kyauk Pan Du, Myo Thu Gyi, Min Gyi (Tu Lar Tu Li), Chein Hkar Li, Tha Yae Kone Tan, Done Paik (Aung Seik Pyin), Maung Hna Ma, U Daung, Nan Yar Kaing, Kyauk Pyin Seik, Kyee Kan Pyin and Tha Pyay Taw in Maungdaw township, Myauk Ye (a) Pan Be Chaung, Zee Hton, Tin May, Nga Yant Chaung (a) Taung Bazar and Thin Ga Net in Buthidaung Township and Zay Di Pyin, Koe Tan Kauk and Chut Pyin in Rathedaung Township. Figure 5 shows an example of this pattern of damage in the village tract of Inn Din, Maungdaw Township.

Figure 5: Pattern of destruction in Inn Din village tract, Maungdaw Township



This image shows a portion of the village tract of Inn Din, Maungdaw Township, as of 9 October 2017, where satellite imagery shows that all the villages have been completely destroyed except for one of them that has a different appearance with more organized structures built with different materials, possibly with tin roofs. A pagoda is also visible in the intact area. Imagery courtesy of DigitalGlobe.

After March 2018 the availability of analyzable imagery has diminished, due to the change in the region from dry to rainy season and the consequential increased presence of thick haze and clouds. Nonetheless, a partially cloudy image collected 9 April 2018 over the Maungdaw Township showed the presence of new destroyed structures, allowing UNOSAT to conclude that, as of that date, the destruction operations were still ongoing. Due to the extensive cloud cover in this April imagery, a new comprehensive damage assessment covering the three affected townships was not possible, but in cloud free areas of the image UNOSAT observed new signs of scorching, burned trees, fields and houses in the northern Maungdaw Township, mainly concentrated around the village of Tone Chang, just slightly affected by destruction at the beginning of September 2017 and now completely destroyed. The area affected by scorching extends for 9 kilometers between the villages of Kyaung Toe and Nga Yant Chang, and from here it runs for 8 kilometers to north-east up until the village of Bwin (Baung). Furthermore, new damaged structures were also detected in the village tract of Taung Pyo Let Yar and in the adjacent village tracts. Using a subsequent image collected 14 April 2018 over part of Maungdaw Township, UNOSAT was also able to identify new damage occurred after the 9 April 2018, for example over the village of Nga Ku Ya (Ku Lar), in the proximity of a recent constructed resettlement camp.

### Terrain Clearance and Construction Visible in Satellite Imagery

UNOSAT analysis identified that approximately 78 out of 392 previously destroyed or partially destroyed villages presented signs of bulldozing or other forms of terrain clearance. The first signs of terrain clearance were visible as early as November 2017 in Maungdaw town, and also in the villages of Ho Kay Day Kone Nar and Zay Di, Kyauk Pan Du village tract, Maungdaw Township, where a new road has been built across the previously destroyed settlements. New bulldozed areas continued to appear in the following months in new additional areas until February 2018. The majority of these areas were located in Maungdaw Township and a few in Rathedaung Township. In 50 of these locations the terrain clearing occurred at a great scale and affected the totality of the village whereas the rest of the villages appeared

only partially bulldozed/cleared as of March 2018. This large scale terrain clearance occurred mostly in southern and central Maungdaw Township and to some extent in northern Maungdaw Township, around the village tracts of Laung Don and Kyein Chaung. Whereas most clearance activity in north Maungdaw Township started in 2017, in the south it mainly began in 2018. The starting dates of clearance in the middle region were more interspersed.

Although in general the large scale bulldozing occurred on previously totally destroyed areas, UNOSAT identified that the clearing operations were also affecting groups of houses that appeared still intact in the almost totally destroyed villages. Examples of this pattern were observed in the villages of Chein Khar Li (West) in Chein Hkar Li village tract, Thaung Paing Nyar in War Cha village tract, Gaw Du Thar Ra (North) in Gaw Du Thar Ra (Ywar Thit Kay) village tract, Tat U Chaung in (Du) Chee Yar Tan village tract and Myin Hlut (Middle and East), Kan Nar Ywar Haung and Shee Dar in Myin Hlut village tract, Maungdaw Township. Figure 6 shows an example of this clearance in Myin Hlut (East).

**Figure 6: Terrain clearance at Myin Hlut (East) village, Maungdaw Township**



These images show a portion of the town of Myin Hlut (East) village, Maungdaw Township, as of 9 January 2018 (left), where a large area of the settlement has been destroyed and a group of houses next to them appear intact. By 13 February 2018 (right), the whole area has been bulldozed or cleared and the previously intact structures are no longer visible. Imagery courtesy of DigitalGlobe.

UNOSAT analysis also revealed that in a total of 36 villages there are signs of construction of new structures as of March 2018. These new construction activities are mostly concentrated in Maungdaw Township, although a few are also observed in Rathedaung and Buthidaung Townships. The majority of these new groups of structures are located near previously destroyed or partially destroyed villages, occupying the surrounding agricultural fields and farmland. However, in 13 of these villages, UNOSAT identified that new structures are being constructed directly occupying the terrain of previously destroyed and bulldozed/cleared areas. In approximately 57 of the previously damaged and bulldozed villages, there are no signs of new construction and as of March 2018 those areas remain unchanged since the bulldozing operations.

The new structures are in the majority possible new houses, sometimes with smaller size and unorganized appearance, which could be related to new permanent housing units or temporary ones associated with construction efforts. In other instances, they have the appearance of bigger development projects, with new roads and larger and more permanent structures, which possibly indicate new model villages under construction. Larger scale construction projects with the appearance of model villages were observed in Pa Da Kar Taung, Thit Tone Nar Gwa Son and (Du) Than Dar in Maungdaw Township. Other groups of organized and permanent houses were detected in Pa Da Kar

Ywar Thit, Kyet Kyein, Ah Htet Pyu Ma and Maungdaw town in Maungdaw Township, Yin Ma Zay in Buthidaung and Koe Tan Kauk in Rathedaung Township. Figures 7 and 8 show examples of two different types of construction observed, including small unorganized structures and larger and perhaps more permanent structures.

**Figure 7: Terrain clearance and new construction at Than Hpa Yar village, Maungdaw Township**



These images show Than Hpa Yar village, Maungdaw Township, on 25 September 2017 (left) and 7 March 2018 (right). As of 25 September 2017, the entire village was destroyed. Dark patches of soil indicate burning as the likely origin for the majority of damage. By 7 March 2018, several structures had been built over part of the affected village. Many more were visible on the agricultural fields surrounding the village, as well as along both sides of the main road. Imagery courtesy of DigitalGlobe.

**Figure 8: Terrain clearance and new construction at Thit Tone Nar Gwa Son village, Maungdaw Township**



These images show Thit Tone Nar Gwa Son village, Maungdaw Township, on 11 October 2017 (left) and 7 March 2018 (right). Imagery shows that a large area of the terrain has been bulldozed, removing the debris from previously destroyed areas and new organized structures and roads have been built at the site. Imagery also shows the presence of smaller and less organized structures built directly in the previously damaged area. Imagery courtesy of DigitalGlobe.

Resettlement camps were also observed in three main areas to the north of Maungdaw town: Aung Zay Ya (Nyein Chan Yay) in Aung Zay Ya (Nyein Chan Yay) village tract, Nga Ku Ya (Ku Lar) in Nga Khu Ya village tract and in Haw Ri Tu Lar and Thar Zay Kone (Thar Zi Kone) in Zin Paing Nyar village tract (see Figure 9). At Haw Ri Tu Lar area, as of 9 January, many excavators were visible at the site and some small terrain clearances had already started. As of 18 March more than 300 structures have already been erected in the villages of Thar Zay Kone (Thar Zi Kone) and Haw Ri Tu Lar over the previously destroyed areas and also covering some of the surrounding agricultural fields. In addition, previously damaged zones have been also cleared in 6 of the surrounding villages in preparations for new construction. Two helipads are also visible at the site. The sites at Aung Zay Ya (Nyein Chan Yay) and Nga Khu Ya (Ku Lar) are considerably smaller and the new constructions are being placed in areas independent of previously damaged sites. First signs of the new developments at these sites started 16 December for Aung Zay Ya (Nyein Chan Yay) and 9 January for Nga Ku Ya (Ku Lar).

**Figure 9: Terrain clearance and new construction at Zin Paing Nyar village tract, Maungdaw Township**



These images show the villages of Haw Ri Tu Lar and Thar Zay Kone (Thar Zi Kone) in Zin Paing Nyar village tract, Maungdaw Township, on 11 October 2017 (left) and 18 March 2018 (right). Imagery from 18 March shows that a large area of the terrain has been bulldozed affecting previously damaged zones and also surrounding agricultural fields. New structures are being built in the bulldozed areas. Imagery courtesy of DigitalGlobe.

In other locations satellite imagery indicates that the new constructions have a security purpose and in general UNOSAT analysis also revealed other signs of security built up across the affected townships, like the construction of smaller security outpost and the enlargement or reinforcement of previously existing security bases.

In the vicinity of the village of Let Thar, in Ah Lel Chaung village tract, Buthidaung Township, a new large construction site is visible as of March 2018 with new roads and structures being built (see Figure 10). The appearance of the buildings, with significantly larger size and the presence of a perimeter fence indicate that this is possibly a new security base under construction. In the village of Kan Kya (South), Myo Thu Gyi village tract, Maungdaw Township, imagery also shows that large structures are being built as well as a defensive perimeter fence. In this case, the new possible security base is constructed directly on the previously destroyed areas. This same pattern is observed in Inn Din village tract, Maungdaw Township, with new large structures directly constructed where previously destroyed houses used to be.

**Figure 10: Terrain clearance and new construction at Let Thar village, Buthidaung Township**



These images show Let Thar village, Ah Lel Chaung village tract, Buthidaung Township, on 11 October 2017 (left) and 18 March 2018 (right). Imagery shows the presence of a large construction site as of 18 March with newly built roads and large structures. The appearance of the structures being built and the presence of a fence around the area indicates that it could possibly be a new security base under construction. Imagery courtesy of DigitalGlobe.

In addition to the larger size security facilities, several new security outposts were also built in isolated and elevated areas along the Mayu mountain range. Others were also built very close by or within populated places, like in Maung Nu, Chin Tha Mar village tract, Buthidaung Township, and Yae Myet Taung and Aung Zay Ya (Nyein Chan Yay) in Maungdaw Township.

Along with the new security features, different types of construction works were observed in multiple pre-existing security facilities across Northern Rakhine. For instance new secondary defensive walls covering a larger perimeter have been built around the security facilities present at Inn Din (Middle), Maungdaw Township and in Zay Di Pyin, Rathedaung Township. These larger perimeter fence are an indication of increase defensive measures or possibly preparations for expansion. The same pattern with new security fences is also observed in two smaller security outposts located at Ka Nyin Taw, Maungdaw Township, and Ta Man Thar Bo Hmu Gyi, Ta Man Thar village tract, Buthidaung Township. Reinforced measures in the form of possible new fences or trenches within the limits of the compound are detected at security facilities present at Tha Pyay Taw, Tha Pyay Taw village tract, Maungdaw Township (see Figure 11), and Pale Taung, Chin Tha Mar, Buthidaung Township.

**Figure 11: Terrain clearance and new construction at Tha Pyay Taw village tract, Maungdaw Township**



These images show a military facility located in Tha Pyay Taw village tract, Maungdaw Township, on 2 December 2017 (left) and 9 January 2018 (right). Imagery shows the presence of a possible new trench constructed inside the limits of the compound. Imagery courtesy of DigitalGlobe.

Construction of at least 6 new large buildings at the security bases at Let Wea Det Pyin Shey village tract, Buthidaung Township, and works of expansion are visible in a nearby security facility located 1 km west of Buthidaung town. Possible signs of expansion are detected in a small security terrain in Yin Ma Zay, Nga Yant Chaung (a) Taung Bazar, Buthidaung Township, where there are signs of construction works and 2 new helipads have been built.

Significantly, increased security built up is observed near the resettlement camp at Zin Paing Nyar, where a new security fence is being built around a security base located roughly 1 km east of the new camp, near Thea Chaung Ywar Thit Kay village, Kyauk Hlay Kar village tract in Maungdaw Township (see Figure 12). Increased security is also observed nearby Aung Zay Ya (Nyein Chan Yay) camp, where a new security outpost was built during early 2018 (see Figure 13).

Figure 12: New defensive measures at a facility located in Kyauk Hlay Kar village tract, Maungdaw Township



These images show a security facility located in Kyauk Hlay Kar village tract, Maungdaw Township, on 2 December 2017 (left) and 20 February 2018 (right). Imagery shows the presence of a possible new defensive wall constructed inside the limits of the compound. Imagery courtesy of DigitalGlobe.

Figure 13: New security outpost located at Aung Zay Ya (Nyein Chan Yay) in Aung Zay Ya (Nyein Chan Yay) village tract, Maungdaw Township



These images show a new facility located nearby Aung Zay Ya (Nyein Chan Yay) in Aung Zay Ya (Nyein Chan Yay) village tract, Maungdaw Township, on 25 September 2017 (left) and 7 March 2018 (right). Imagery shows the presence of a new area of terrain cleared where new structures have been built and are surrounded by a defensive trench. Imagery courtesy of DigitalGlobe.



Analysis also indicates that in general further infrastructure is being developed in the affected townships and that there are works for improving the condition of roads: multiple secondary roads are under development, and two large roads are being constructed across the mountainous area to improve the East-West transit. One of these roads connects the town of Goke Pi in Buthidaung Township with Kyein Chaung in Maungdaw Township, where a large area of terrain is cleared and prepared for new construction. The second one connects Ah Htet Nan Yar in Rathedaung Township with Ho Kay Day Kone Nar in Maungdaw Township, where construction of new houses and terrain clearance is also visible. In some instances, these new roads are constructed across the previously destroyed villages, like in Ah Htet Nan Yar in Rathedaung Township and Zay Di in Maungdaw Township. Other indications of the development in the area are the presence of new antennae and a possible new utility line between Rathedaung and southern Buthidaung Townships.

After March 2018 image collections in Northern Rakhine become scarcer and often very cloudy, which prevents UNOSAT from conducting a comprehensive assessment across the three affected townships after March 2018. Nonetheless, UNOSAT reviewed imagery collected between the months of April and July 2018 that had multiple cloud covered areas and analysis showed that there are no signs of additional large scale terrain clearance operations in the areas reviewed. Construction of new structures is still ongoing in the resettlement camp at Haw Ri Tu Lar and in other areas where new construction was previously observed like in Pa Da Kar Ywar Thit, Pa Da Kar Ywar Thit village tract, Pa Da Kar Taung in Net Chaung village tract or (Du) Than Dar, Than Dar village tract. Moreover, construction of new houses in additional areas was occasionally observed like in Bwin (Baung) in Ye Aung San Ya Hpway village tract, Done Paik in Done Paik (Aung Seik Pyin) village tract and Ta Man Thar Bo Hmu Gyi in Ta Man Thar village tract.

Below, two areas in Maungdaw townships, where reconstruction efforts have been identified, are described in detail in order to provide an overview of the pattern of destruction, clearing and reconstruction observed in satellite imagery.

#### **Inn Din village tract in Maungdaw Township, Rakhine State**

Within the Inn Din village tract of south Maungdaw Township, most structures were destroyed by 25 September 2017. Only one village located in the north and containing a pagoda remained completely intact. Affected areas and some surrounding agricultural fields were cleared as of 16 February 2018. New structures appeared at this time in the north, some of which were markedly larger than those of the neighboring unharmed village. The size and appearance of these new large structures is an indication of a possible new security facility under construction. A new road and preparations for further construction were also visible nearby. To the south, a single standing structure and a few trucks were observed amid newly leveled terrain. By 7 March 2018, additional structures emerged in the north. Many smaller and possibly temporary structures also appeared in the south. Within the vicinity of both areas more land was cleared for potential development (see Figures 14 and 15).

**Figure 14: Terrain clearance and new construction in Inn Din (Rakhine) village, Maungdaw Township**



The images above show part of Inn Din (Rakhine) village, Maungdaw Township, on 9 October 2017 (left) and 7 March 2018 (right). The village was destroyed as of 9 October 2017, with dark soil as indication of fire as the cause. By 7 March 2018, the majority of affected terrain had been cleared and several large structures built. New roads and foundations for further construction were also visible in another impacted area and surrounding agricultural fields. Imagery courtesy of DigitalGlobe.

**Figure 15: Terrain clearance and new construction at Inn Dinn (Middle) village, Maungdaw Township**



These images illustrate the southern portion of Inn Din (Middle) village, Maungdaw Township, on 9 October 2017 (left) and 7 March 2018 (right). As of 9 October 2017, this part of the village was destroyed with burn marks visible where houses previously stood. By 7 March 2018, the affected area appeared to have been bulldozed. A few new roads and several small possible temporary structures were visible between the two cleared zones. Imagery courtesy of DigitalGlobe.

### Net Chaung and Pa Da Kar Ywar Thit village tracts in Maungdaw Township, Rakhine State

Near the border of the Pa Da Kar Ywar Thit and Net Chaung village tracts in north Maungdaw Township, the majority of structures were destroyed by 25 September 2017. The first new structure built over the impacted land was visible as of 11 October 2017. Additional structures continued to appear in affected areas and their general vicinity, particularly around Than Hpa Yar and Pa Da Kar Taung villages, until 28 December 2017. Preparations for and construction of a large new development site near Pa Da Kar Taung began during this time as well. It consisted of several intersecting roads, some structures, and two helipads. More progress occurred at the start of 2018 during the months of January and February. By 18 March 2018, many structures had been built at the Pa Da Kar Taung development site. A smaller though notable development with a few structures and several foundations was also observed to the south of Pa Da Kar Ywar Thit village. These developments are illustrated in Figures 16 and 17.

**Figure 16: New development site visible at Pa Da Kar Taung village, Maungdaw Township**



The images above show the southern part of Pa Da Kar Taung village, Maungdaw Township, and its surrounding area on 25 September 2017 (left) and 7 March 2018 (right). Burned areas in this village and Pa Da Kar Ywar Thit village to the south were visible as of 25 September 2017. By 7 March 2018, some of Pa Da Kar Taung village appeared to have been cleared and many small structures built. Agricultural fields to the east were converted into a development site consisting of several new roads, larger structures, foundations, and two helipads. Imagery courtesy of DigitalGlobe.

Figure 17: Terrain clearance and new construction at Pa Da Kar Ywar Thit village, Maungdaw Township

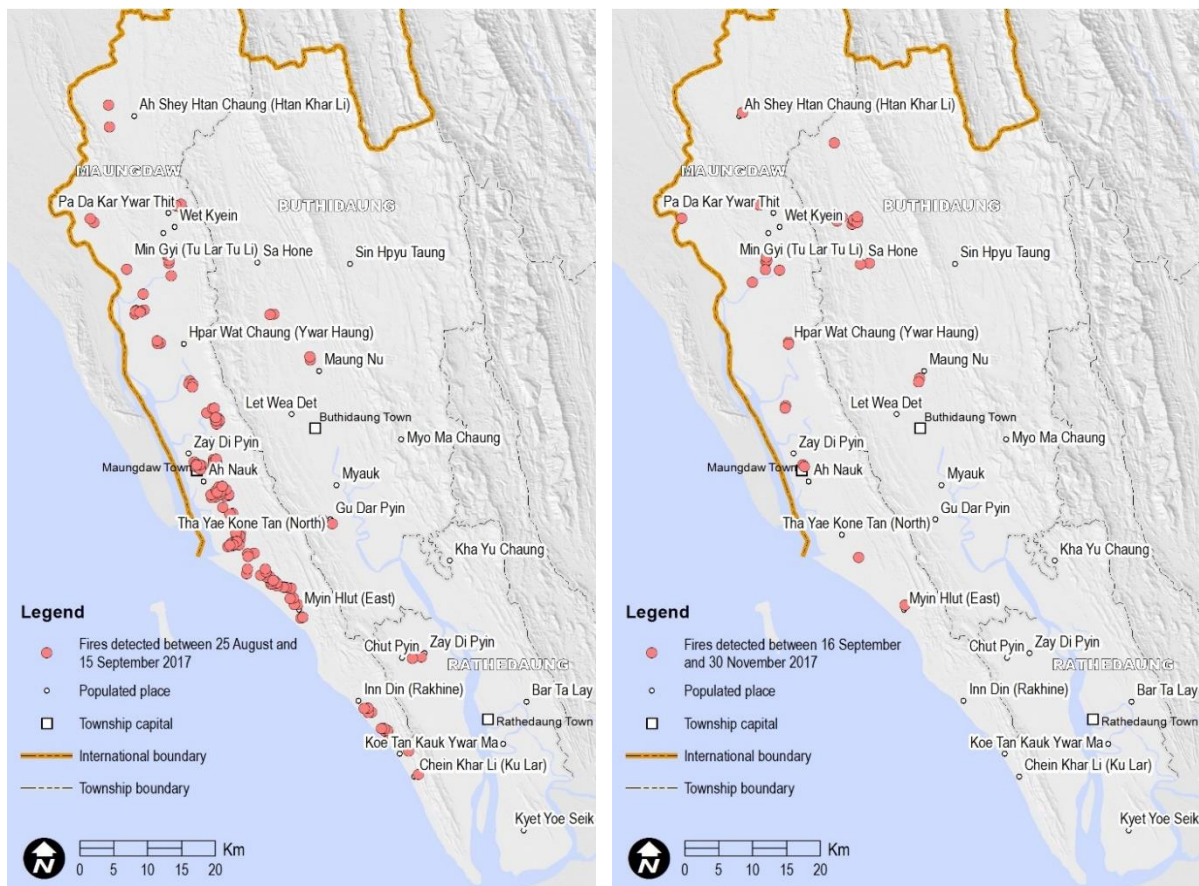


The images above illustrate southern Pa Da Kar Ywar Thit village, Maungdaw Township, on 25 September 2017 (left) and 7 March 2018 (right). This portion of the village was destroyed as of 25 September 2017, with visible scorching marks from fire. By 7 March 2018, some small structures appeared over affected areas near the main road. East of the village, a development site with a few new roads, structures and several foundations was visible over agricultural fields. Imagery courtesy of DigitalGlobe.

### Fire Detection Analysis

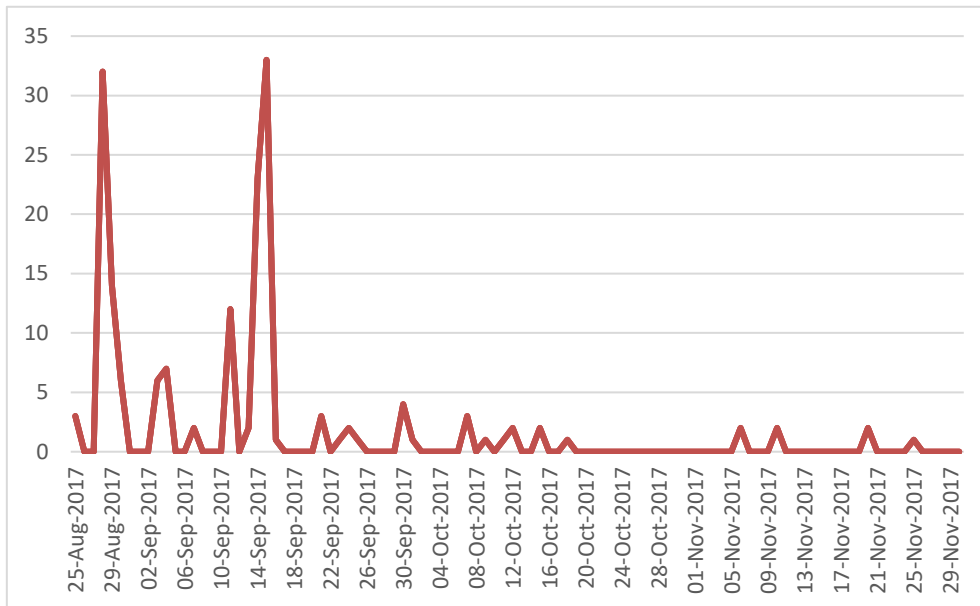
UNOSAT reviewed the satellite-detected fire detections, collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS). Between 25 August and 30 November 2017 these sensors detected a total of 170 fires, 147 of them in Maungdaw, 19 in Buthidaung and 4 in Rathedaung Townships. Of these 170 fire detections, 140 of them occurred between 25 August and 15 September 2017, 130 of them in Maungdaw Township. These results are illustrated in Figure 18 and Figure 19.

Figure 18: Spatial distribution of satellite detected fires, 25 August – 30 November 2017



The images above illustrate the spatial distribution of satellite detected fires between 25 August and 15 September 2017 (left) and between 16 September and 30 November 2017 (right).

Figure 19: Daily sum of satellite-detected fires, 25 August – 30 November 2017



This graph shows the daily totals of fire detections in Rathedaung, Buthidaung and Maungdaw Townships between 25 August and 30 November 2017, with the highest number of detections occurring on 28 August and 15 September 2017.

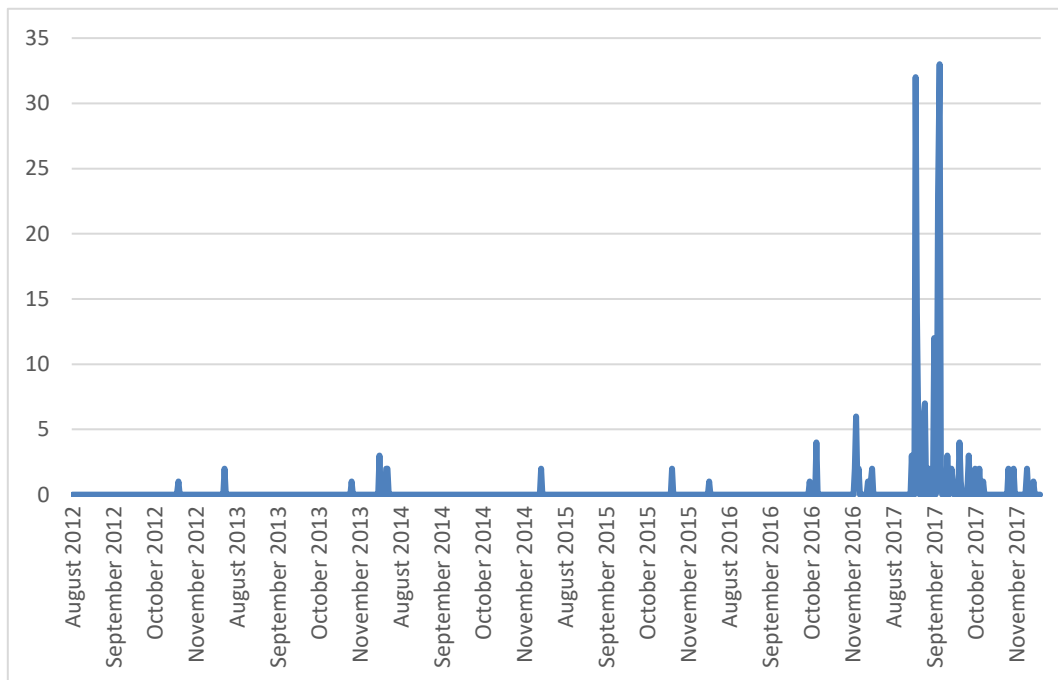
MODIS fire detection data analysis also focused on detections occurring during the August through November period from 2001 through 2017. This assessment indicated that fire detections were exceedingly rare in the area during these months until August 2017. Specifically, one fire was detected in Buthidaung Township in November 2010, and three fires were detected in Maungdaw Township in November 2016. There were no other detections during these months in the entire MODIS fire detection record until 25 August 2017, when two fire detections occurred in Rathedaung Township. From 26 August 2017 until the end of November 2017 an additional 20 MODIS fire detections occurred in the three affected townships of Rakhine state. A total of 22 MODIS detections therefore occurred from 25 August through 30 November 2017. In summary, analysis shows that there is not a seasonal pattern that explains the number of fires detected during this period, since in the past 16 years there was not a similar elevated number of fires detected during the period of August – September.

VIIRS fire detection data was also similarly analyzed for the August through November period of 2012 through 2017 obtaining the same conclusion. This analysis indicated that 33 fires were detected in the affected townships during the August through November months from 2012 through 2016. During August through November 2017, 148 fires were detected in the three affected townships. MODIS and VIIRS detections in the August through November period from 2012 through 2017 are illustrated in Figure 20.

In summary, of the 207 fires detected by both the MODIS and VIIRS sensors in Rathedaung, Buthidaung and Maungdaw Townships during the August through November period in 2001 through 2017, 82% occurred during August through November 2017.

UNOSAT also assessed fire detections within the period of 5 September through 16 September 2017 using both the MODIS and VIIRS sensors. Twenty-six village tracts saw 72 fire detections during this period, with one in Buthidaung Township and the remained in Maungdaw Township. The vast majority of these detections occurred on 11, 14, and 15 September 2017. Only two of these 26 village tracts had seen fire detections during the period of 25 August – 5 September 2017.

Figure 20: Daily sum of fires detected in the months of August through November, 2012 - 2017



This graph shows the daily totals of fire detections in the affected townships during the August through November period during the years 2012 through 2017. Fire detections during these months were rare in the affected townships until 2017, when large increases are observed.

## Conclusion

UNOSAT analysis of Buthidaung, Maungdaw, and Rathedaung Townships in Rakhine State using satellite imagery spanning August 2017 through March 2018 indicates clearly identifiable widespread destruction, debris clearing, and construction patterns across the area. Specifically, using the MIMU list of settlements, UNOSAT identified a total of 392 settlements showing some signs of destruction or damage. UNOSAT identified an additional 35 settlements which may have been excluded from the MIMU list that also showed signs of destruction or damage. Using a statistical technique, UNOSAT estimates that approximately 37,700 structures were destroyed or damaged in these affected settlements.

Both analysis of damage and fire detections indicate that during the first weeks of the conflict the destruction operations were the most intense since the majority of the fires detected occurred between 25 August and 15 September 2017 and approximately 80% of the damage was already present by 16 September. Though cloud cover in imagery introduces some uncertainty it's possible that almost 85% of the total destruction actually occurred by 16 September. Analysis of fire detection data also revealed that 2017 had an unprecedented concentration of fires in the August through November months versus previous years. Additionally, the period from 5 September to 16 September saw many active fire detections and there is no indication that destruction abated in this period.

Notably, although with not the same intensity, destruction did continue into late 2017 and in 2018, affecting previously damaged settlements but also expanding to new areas and affecting previously intact settlements. Since 11 October 2017, 79 previously intact villages were affected by new damage. Moreover, a partly cloudy image from 9 April 2018 reviewed by UNOSAT indicated destruction is still ongoing as of that date. Overall destruction was concentrated in Maungdaw Township, though Buthidaung and Rathedaung Townships were also widely affected of course.

UNOSAT also analysed terrain clearance and construction in the affected townships and saw such activities underway as of November 2017. Approximately 78 previously destroyed or partially destroyed villages presented signs of bulldozing or other forms of terrain clearance and new structures were visible in 13 of them as of March 2018. The majority of this activities are again observed in Maungdaw Township. Multiple sites for clearing and construction are also visible although not located directly in previously destroyed areas. These new constructions include the development of possible new villages and resettlement camps. Analysis also revealed that there are signs of security built up across the three townships with new security infrastructure being built and possible reinforcement of some of the previously existing security bases.