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Strategic Analyses of the Hydropolitical Conflicts Surrounding the Grand Ethiopian Renaissance Dam

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Abstract
Hydropolitical conflicts between the Eastern Nile countries over the Grand Ethiopian Renaissance Dam (GERD) are systematically analyzed at three points in time: just before the announcement of construction by Ethiopia on April 11, 2011, before the negotiations in early January 2014, and late August 2014. Hypergame theory, as developed within the framework of the Graph Model for Conflict Resolution for handling misperceptions, is used to gain strategic insights into these conflicts and to ascertain the possible resolutions of the disputes. In all of three conflicts, the key decision makers are Egypt and Sudan, the downstream countries, and Ethiopia, the upstream nation. The findings from the analyses demonstrate the significant utilization of strategic surprise, a decisive act in which a decision maker intentionally exercises a course of action in the dispute that is hidden to its opponents in order to attempt to reach a more desirable outcome for itself. In particular, both Egypt and Sudan were caught by surprise when Ethiopia publicly announced on April 11, 2011 that it was going to build GERD, since no prior notification was given. Because Ethiopia was aware of Egypt and Sudan's misperception this dispute is modeled as a second level hypergame. The conflict investigations also show that the geopolitical and economic changes in Egypt, Sudan, and Ethiopia allowed Ethiopia to construct the dam without any harsh confrontation with Egypt and Sudan.

Keywords Conflict resolution · Graph model · Hypergames · Misperceptions · Nile River · The Grand Ethiopian Renaissance Dam

1 Introduction

Globally, there are a number of international rivers on which large water resources development facilities have been constructed in both upstream and downstream coun-

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tries. The Colorado River, for example, is an international river shared by the United States and Mexico (MIT 2014). This river has multiple storage facilities in both the upstream and downstream countries with an international agreement that coordinates their operation. What makes the Nile River situation unique is that, in the near future, two hydraulic dams, the Grand Ethiopian Renaissance Dam (GERD) and Aswan High Dam (AHD), each with a sufficient storage capacity to hold the annual flow of the Nile River, will be working without any international agreement to coordinate their operations (MIT 2014). With a length of 6800 km, the Nile River is one of the longest river systems on earth and is shared by 11 African countries: Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, and Uganda, as shown on the map in Fig. 1. Disputes have arisen with the decline in water resources due to rapid population increases, development growth in

Fig. 1 The Nile River Basin

Nile Basin countries, inequitable allotment of the Nile River water, and inequitable hydraulic development on the Nile River (Salman 2013; Cascão and Alan 2016).

The Nile Valley covers 3.18 million km^2 of Eastern Africa, which represents approximately 10.3% of the total area (Craig 1991). As can be seen in Fig. 1, the Nile River is fed by two main tributaries: the White Nile and the Blue Nile River. Lake Victoria, which is located in east central Africa on the frontiers of Uganda, Kenya, and Tanzania, is the primary water source of the White Nile. This lake is the second largest freshwater reservoir on earth. The Blue Nile River, on the other hand, is formed by Lake Tana in the Ethiopian highlands. The White and Blue Niles converge in Sudan to form the Nile River, which flows from south to north through Egypt and discharges into the Mediterranean Sea. Some of the water from the Nile River is stored in Egypt by AHD in the artificial Lake Nasser (Shahin 1985). The White and Blue Niles, respectively, contribute 30% and 57% of the total water in the Nile River (Craig 1991). The remaining 13% comes from a number of small rivers.

The most recent conflict regarding the Nile Basin erupted on April 11, 2011, when Ethiopia publicly announced the launch of its federal hydroelectric dam project, called the Grand Ethiopian Renaissance Dam (GERD). As will be mentioned later, Ethiopia's ambition to build a hydroelectric dam in the Ethiopian highlands within the Blue Nile River near the eastern Sudanese border, (see Fig. 1), goes back to 1958. Ethiopia's unilateral decision to violate the 1929 and 1959 agreements and start constructing the dam on the Blue Nile River without prior notification to or approval from Egypt and Sudan has been the cause of a series of conflicts that began just before April 2011 (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; MIT 2014; Abdelhady et al. 2015; Cascão and Alan 2016). In fact, Egypt and Sudan were aware of Ethiopia's intention to build the dam on the Blue Nile River, but they chose not to mitigate this risk because they underestimated Ethiopia's capability regarding the building of the dam. In particular, Egypt and Sudan had failed to predict that Ethiopia would start the construction of the dam without the need to secure foreign investments. Moreover, both Sudan and Egypt were consumed by severe internal political turmoils and therefore, the problem of Ethiopia possibly building a dam on the Blue Nile was not of high importance or concern to them at that time. Thus, Egypt and Sudan faced a strategic surprise when Ethiopia announced on April 11, 2011 the commencement of the initial phase of the dam construction as a national project, which was being commissioned in the absence of foreign investments.

Water disputes have been extensively studied during the last decades, and different methods have been utilized to model and analyze them (Madani 2010). For example, a game theoretical approach, the Graph Model for Conflict Resolution (GMCR), has been utilized to study a generic version of the ongoing Jordan River dispute (Madani and Hipel 2007) and the Nile River Basin conflict before the Egyptian revolution, which commenced on January 25, 2011 (Madani et al. 2011). Within this technique, complete information and common perception among the participating decision makers (DMs) are assumed. There is a stream of articles in the literature that examined the conflict over GERD. For instance, the potential scenarios of the hydropolitical game between Ethiopia, Sudan, and Egypt over GERD were explored by Sammaan (2014). Moreover, Cascão and Alan (2016) argued that the establishment of GERD

will promote possible cooperation between the Eastern Nile countries in light of the geopolitical and economic changes.

The purpose of this research is to investigate in depth the disputes between the Eastern Nile countries—Egypt, Ethiopia, and Sudan—over GERD, in order to provide strategic insights and predict resolutions. The hypergame method in graph form, which models and analyzes real-world disputes under different levels of perception among the participating DMs (Aljefri et al. 2017, 2018a), will be used to study these conflicts. This technique is designed to be applied when there are discrepancies in DMs' perceptions of a dispute, perhaps because of the asymmetry of knowledge or a misunderstanding of the actual environment of the conflict among the participating DMs. In this case, GMCR standard solution concepts cannot be applied; hypergame stability analysis is introduced as a new theoretical procedure that extends GMCR's existing solution concepts to circumstances when DMs have a different interpretation of the real-life conflict. The overriding purpose of hypergame analysis in graph form is to foretell the possible equilibria of the dispute when DMs are not playing the same game.

More specifically, this article demonstrates, for the first time, the applicability and efficacy of employing a second-level hypergame in graph form for addressing challenging real-world conflict. In particular, the GERD dispute occurred just before April 11, 2011 is modeled, for the first-time in this research within the architecture of a second-level hypergame in graph form. In this conflict, Egypt and Sudan underestimated Ethiopia's capability of building a dam in the absence of foreign investment, and Ethiopia was aware of Egypt and Sudan's misperception.

The GERD dispute since the Egyptian revolution of January 2011 is analyzed at three points in time: the conflict just before April 11, 2011, which involves the use of strategic surprise by the Ethiopian government, the negotiation in early January 2014, and the negotiation in late August 2014, as shown in Fig. 2.

The paper is structured as follows. First, an overview of the Nile Basin treaties, related initiatives, and Eastern Nile countries' political and economic changes is provided. Next, the modeling and analysis of the dispute just before April 11, 2011, the negotiation in early January 2014, and the negotiation in late August 2014 are conducted. The evolution of the conflicts and key insights are discussed at the end of the article.

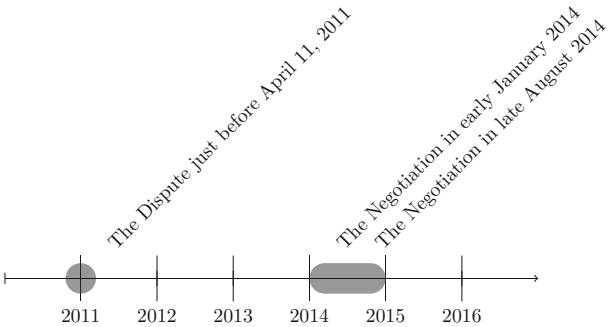

Fig. 2 The hydropolitical conflict timeline

2 Background

In this section the historical Nile Basin treaties are reviewed first. Next, a discussion about the Nile Basin Initiative is provided. Lastly, the geopolitical and economic changes in the Eastern Nile countries are highlighted to understand the cause of the conflicts.

2.1 Nile Basin Treaties

During the British colonial period, many agreements were made regarding the Nile River water allotment among the countries of the Nile Basin. These protocols were designed to protect Britain's interest in downstream states, ensuring that both Egypt and Sudan received a significant and sustainable flow of water from the Nile River, for agricultural and industrial production (Odidi 1994; Swain 1997; Degefu 2003; Madani et al. 2011; Salman 2013, 2016). However, these agreements resulted in inequitable rights regarding the use of the Nile River water by the countries in the region.

The 1902 Nile treaty between the United Kingdom (UK) (on behalf of Sudan) and Ethiopia aimed to establish a border between Ethiopia and Sudan. This agreement stipulated that Ethiopia could not implement any hydraulic project in the Blue Nile River, or Lake Tana, that would capture the natural flow of the Blue Nile River without first reaching an agreement with Britain. Based on Ethiopia's understanding of the agreement, this country could use the water in Lake Tana and the Blue Nile River as long as it did not stop the flow of water. Hence, Ethiopia did not interpret the UK's understanding of the agreement as being preventive to using the water in Lake Tana or the Blue Nile River. Therefore, Ethiopia claimed that its understanding of the agreement was valid, and continued to dispute the validity of the 1902 agreement (Odidi 1994; Swain 1997; Degefu 2003; Madani et al. 2011; Salman 2013, 2016).

After Egypt achieved its independence from UK in 1922, Britain (on behalf of Britain's colonies of Kenya, Uganda, Tanganyika, and Sudan) signed the Nile Water agreement with Egypt in 1929. None of the upstream countries except Ethiopia was independent at the time. This agreement granted Egypt an annual flow of 48 billion cubic meters (BCM) of the Nile River water, the right to develop any project on the Nile River without notifying upstream countries, and the right to stop any hydraulic project by upstream countries that would alter the flow of the Nile River. Moreover, due to Britain's interest in Sudan, the agreement granted Sudan an annual flow of 4 BCM of the Nile River water. The agreement thus left 32 BCM of Nile River water unallocated (Odidi 1994; Swain 1997; Degefu 2003; Madani et al. 2011; Salman 2013, 2016).

After Sudan gained its independence in 1956, it requested to renegotiate the 1929 agreement with Egypt to gain access to additional water that would satisfy Sudan's needs. Therefore, in 1959, Egypt and Sudan signed the Nile River water treaty for full utilization of the Nile River water. According to this agreement, the annual water allotments of Egypt and Sudan increased from 48 to 55.5 BCM and from 4 to 18.5 BCM, respectively. In addition, the agreement permitted Sudan to construct hydraulic projects on the Nile River that could regulate its flow. Egypt maintained all the rights that were

given to it by the 1929 agreement. Upstream countries were prohibited from building any hydraulic infrastructure and from using the Nile River water (Odidi 1994; Swain 1997; Degefu 2003; Madani et al. 2011; Salman 2013, 2016).

The upstream countries did not accept either the 1929 or 1959 agreement, yet they were unwilling to actively oppose them due to their political instability and poor economic situations (Odidi 1994; Swain 1997; Degefu 2003). Soon after the 1959 agreement had been signed, Ethiopia criticized the agreement, stressing its sovereignty over the water in Lake Tana and the Blue Nile River that flows in its territory (Odidi 1994; Swain 1997; Degefu 2003; Madani et al. 2011; Salman 2013, 2016). Therefore, Ethiopia, with the support of the United States Bureau of Reclamation (USBR), investigated the possible construction of hydropower dams on Ethiopia's Blue Nile River between 1958 and 1965 (USBR 1964; Swain 1997; Blackmore and Whittington 2008; Cascão and Alan 2016). The USBR decided to support Ethiopia after Egypt began building the AHD with huge support from the Soviet Union (Shupe et al. 1980; Wright et al. 1980). The studies had identified possible sites for constructing a hydropower dam and for implementing irrigation projects. However, between 1958 and 1999, Ethiopia was unable to acquire the necessary funds to implement the plans for these projects, due to its political instability, severe poverty, and harsh civil war (USBR 1964; Swain 1997; Blackmore and Whittington 2008; Cascão and Alan 2016; AfDB et al. 2016; Yihdego et al. 2016).

With the absence of colonial powers in Africa, it became evident that both the 1929 and 1959 agreements were unsustainable. Believing in the unfair agreements between upstream and downstream countries, the nations in the region began to establish a cooperative institution that promoted fair use of the Nile River water in 1992. Their efforts resulted in the formation of the Nile Basin Initiative (NBI) in 1999, which is discussed in the next subsection.

2.2 The Nile Basin Initiative

The NBI was launched in 1999 for the purpose of promoting sustainable development through cooperative and fair allotment of the Nile River water among countries in the region (Salman 2013). This important initiative brought upstream and downstream countries together to investigate mutually beneficial projects in the Nile Basin. International organizations such as the World Bank and United Nations Development Program (UNDP) facilitated the establishment of the NBI. Indeed, the NBI was the first undertaking to garner strong international support. It aimed to identify possible regional investment opportunities in different sub-regions of the Basin that would provide mutual benefits for the countries therein. One of the first studies done by the NBI was conducted by the Joint Multipurpose Project (JMP) of the Eastern Nile countries in 2008. This study concluded that the Blue Nile River in the Ethiopian highlands provides a good investment opportunity for developing a large hydroelectric dam that has mutual benefits for Egypt, Sudan, and Ethiopia (Blackmore and Whittington 2008). This proposed project was expected to reduce the amount of water loss, manage floods, and improve agricultural production in Egypt, Ethiopia, and Sudan (Brunnée and Toope 2002; FAO 2002; The World Bank 2009).

Ethiopia, a country with huge ambitions to construct hydroelectric dams on the Blue Nile River, viewed the project proposed by the JMP of the Eastern Nile countries as the first real opportunity to construct such a dam on the Blue Nile River, with the benefit of jointly funding the project with the Eastern Nile countries, Egypt and Sudan, through the Nile Basin Trust Fund (NBTF) and with substantial aid from the international community (USBR 1964; Blackmore and Whittington 2008; Cascão and Alan 2016). However, after the JMP report was released in 2008, Egypt disputed the validity of the study and rejected the proposals for building a dam on the Blue Nile River, because it believed that the dam would reduce the volume of water reaching Egypt (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016). Ethiopia and Sudan, on the other hand, praised the findings, viewing the project as an excellent opportunity for power trade, flood control, and irrigation projects that would benefit all the Eastern Nile countries. Therefore, from 2008 to 2009, Ethiopia and Sudan tried to convince Egypt to cooperate in the JMP of the NBI, but their efforts did not lead to any result. Until 2010, the NBI was not a legally binding agreement. Thus, the parties could walk away from the initiative without suffering any negative consequences.

To make the NBI a legally binding agreement for all Nile Basin countries, the parties involved worked from 1991 to 2010 to draft a Cooperative Framework Agreement (CFA). The objectives of the CFA are to give the right to each Nile country to use the Nile River water within its borders and to specify a number of factors that determine the equitable utilization of the Nile River water among the countries of the region. However, the situation of ratifying the CFA intensified when both Egypt and Sudan refused to sign the CFA of the NBI in 2010 due to Article 14b regarding water security (Dahan 2009; Nile Basin Initiative 2010). This article required all Nile Basin countries to have a fair use of the Nile River water. Egypt and Sudan wanted the CFA to maintain their historical rights, which had been granted to them by the 1929 and 1959 treaties. As a result, this window of opportunity for Ethiopia, Sudan, and Egypt to engage in any mutually beneficial and cooperative hydraulic projects was shut (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016).

At this point, Ethiopia realized that the development of a hydraulic project within the cooperative framework of the JMP through NBI would not be an option. Hence, Ethiopia returned to considering its national projects on its own and decided to construct a hydroelectric dam on the Blue Nile River, as identified by the USBR in 1964, but larger and with greater capacity (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016). In April 2011, Ethiopia publicly announced the launching of its federal hydroelectric dam project, GERD, on the Blue Nile River near the Sudanese eastern border (see Fig. 1). The economic and political changes occurring in all the Eastern Nile nations allowed Ethiopia to commence the construction of this massive project, which is the first of its kind for Ethiopia. These changes are discussed in the next subsection.

2.3 Eastern Nile Countries: Political and Economic Changes

The geopolitical and economic changes in the Eastern Nile countries set the stage for building GERD. Egypt, for example, which had once been the most stable country in

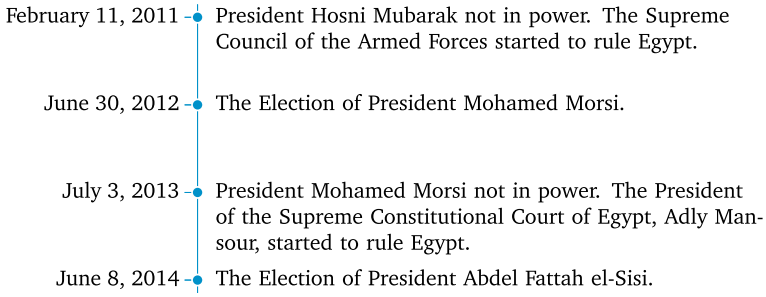

Fig. 3 Egypt's recent political changes

Africa economically and politically, suffered from dramatic political instability due to the Egyptian revolution, which began on January 25, 2011, and continued until the election of President Abdel Fattah el-Sisi on June 8, 2014, as outlined in Fig. 3. As a result of the Egyptian revolution, Egypt's key decision makers were changed more than four times, with each having different views about the country's internal and international policies (Cascão and Alan 2016).

Sudan also experienced significant political and economic transformations. The Comprehensive Peace Agreement (CPA), which was signed in 2005, granted South Sudan its independence from Sudan on July 9, 2011, with South Sudan receiving 48% of Sudan's total oil revenue (Oil and Energy Trends 2011; Aljefri et al. 2014). To compensate for this loss of oil revenue, Sudan worked to diversify its economy, focusing on investments in agriculture and irrigation projects within the Blue Nile River. Thus, Sudan was supportive of the construction of large hydroelectric dams on the Blue Nile River within the Ethiopian highlands as proposed by the JMP of the Eastern Nile River countries. Sudan expected that the proposed dams would grant it extra water that could be used for its ambitious agriculture and irrigation projects (Cascão and Alan 2016; Yihdego et al. 2016).

Unlike other countries in the region, Ethiopia has enhanced its political stability during the last two decades, improved its economy, attracted foreign investments, and conducted business trade with China. According to the World Bank, Ethiopia was ranked as the twelfth-fastest growing economy in the world in 2012 (The World Bank 2013). As can be seen in Fig. 4, Ethiopia's annual gross domestic product (GDP) growth increased from 6.1% in 2000 to 12.6% in 2010, slightly declining to 10.3% in 2014 (The World Bank 2016). In comparison, the world average GDP growth dropped from 4.3% in 2000 to 4.1% in 2010, and further to 2.5% in 2014. These numbers clearly demonstrate that Ethiopia had one of the fastest-growing GDPs in the world during this period. On the other hand, the annual GDP growth in Egypt and Sudan was in line with the international trend (The World Bank 2016). The sustained development of Ethiopia's agricultural and service sectors was the primary reason for its GDP growth (CIA 2016). These factors allowed Ethiopia to commence construction of GERD on April 11, 2011 as a national project that was claimed not to have any real foreign investments (Cascão and Alan 2016).

The perceived weak economic situation in Ethiopia, as well as the political instability in both Egypt and Sudan, influenced the latter two countries' underestimation of

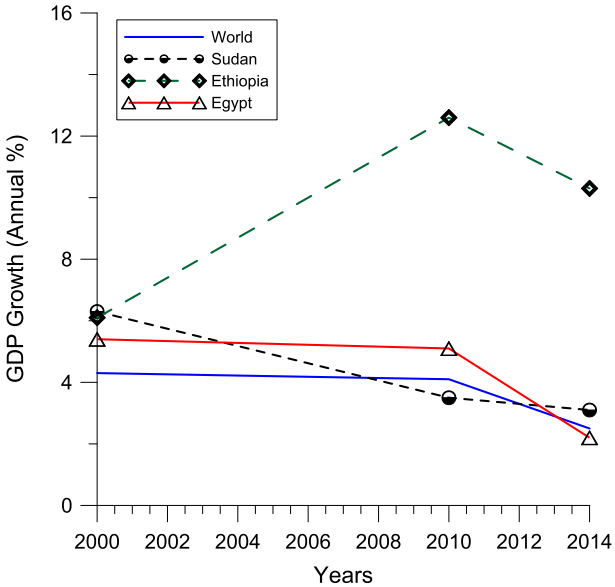

Fig. 4 The annual GDP growth of the Eastern Nile countries in comparison with global overall annual GDP growth

Ethiopia's actual capability regarding the construction of the dam. Ethiopia, however, was aware of Egypt and Sudan's misperceptions and, as a result, utilized this information to achieve better results in the conflict. The pre-April 11, 2011 conflict could not be modeled or analyzed within the traditional GMCR, as it assumes a common perception among the engaging DMs. Instead, the second-level hypergame in graph form is capable of handling the situation under investigation.

3 Hypergame Theory

A hypergame is a decision-making system suited to investigating a diverse range of real-life disputes under different degrees of perception among the engaging DMs (Bennett 1977, 1980; Takahashi et al. 1984; Hipel et al. 1988; Wang et al. 1988, 1989; Aljefri et al. 2015, 2016, 2017, 2018a). Therefore, a hypergame is designed in a hierarchical fashion to account for various levels of misperception among DMs. For instance, if DMs correctly perceive the dispute and are aware of each other's options and preferences, the dispute is a zero-level hypergame, denoted as H^0. A first-level hypergame, denoted as H^1, on the other hand, is a situation in which one or more DMs misperceive the real-life dispute. Hence, a collection of subjective games is modeled, each of which describes a given DM's perception of the actual event. Furthermore, if at least one DM is aware of its opponents' individual games, then the dispute is a second-level hypergame, denoted as H^2. In H^2, a DM is aware of not only its own subjective game but also its opponents' subjective games. Therefore, within H^2, a DM will utilize this extra information to attempt to achieve a better outcome for itself

in the conflict event. The mathematical structure of a zero-level hypergame in graph form is reviewed first.

3.1 Zero-Level Hypergame in Graph Form

The mathematical structure of H^0 in graph form is identical to the mathematical composition of the Graph Model for Conflict Resolution (GMCR), as both methods model and analyze a conflict situation under the assumption of complete information (Aljefri et al. 2018a). The graph model (Kilgour et al. 1987; Fang et al. 1993), denoted as G, which is identical to H^0, can be defined as follows:

$$H^0 = G = \langle N, S, \{A_i : i \in N\}, \{\succsim_i : i \in N\}\rangle \tag{1}$$

The elements of the graph model are: $N = \{1, 2, \ldots, n\}$ is the set of DMs; $S = \{s_1, s_2, \ldots, s_m\}$ is the set of feasible states for the conflict and depicts the vertices for the directed graph; A_i denotes the set of possible state transitions for *DM i* from one state to another state in S and also depicts the arcs for the directed graph; $\succsim_i$ symbolizes *DM i's* preferences over the state space S such that $s_1 \succ_i s_2$ means that i preferred s_1 over s_2, and $s_1 \sim_i s_2$ means that s_1 and s_2 are equally preferred by i.

The analysis of the game starts by investigating DMs' possible moves and counter-moves according to a range of stability definitions, popularly referred to as solution concepts (Fang et al. 1993; Madani and Hipel 2011). The aim is to identify the stability of states for each DM under a particular solution concept. A state that is stable for every DM based on a given solution concept is an equilibrium state under that particular solution concept for the dispute. The most commonly utilized stability definitions in GMCR are Nash stability (Nash 1950, 1951), sequential stability (SEQ) (Fraser and Hipel 1979, 1984), general metarationality (GMR) (Howard 1971), and symmetric metarationality (SMR) (Howard 1971). These four solutions concepts depict the possible human behavior under conflict. In the next subsection, the mathematical modeling of H^1 in graph form is reviewed.

3.2 First-Level Hypergame in Graph Form

A first-level hypergame with n-DM in graph form is mathematically defined as follows (Aljefri et al. 2018a):

$$H^1 = \langle G_i : i \in N\rangle \tag{2}$$

G_i is *DM i's* subjective game and is defined as follows:

$$G_i = \langle N_i, S_i, \{A_{ji} : j \in N_i\}, \{\succsim_{ji} : j \in N_i\}\rangle \tag{3}$$

The elements of G_i are: $N_i \subseteq N$ is the set of DMs as perceived by *DM i*; $S_i \subseteq \hat{S}^1$ is the set of feasible states as perceived by *DM i* in its subjective game and $\hat{S}^1$ is the universal set of the states for the entire first-level hypergame; A_{ji} denotes the possible

state transitions for *DM j* from one state to another state in S_i as perceived by *DM i*; $\succsim_{ji}$ symbolizes *DM j's* preferences over the outcome space S_i as perceived by *DM i*.

An important step in any conflict study is to obtain the relative preferences of each DM in which a given state may be more preferred, equally preferred or less preferred for the DM. When the states are ranked from most to least preferred for the DM where some sets of states may be equally preferred, the preferences are assumed to be transitive. One useful way to obtain transitive preference information is to employ what is called option prioritization in which preferences are expressed using preference statements listed from most to least important (Fraser and Hipel 1988; Hipel et al. 1997; Fang et al. 2003a). As explained later, options are courses of actions which DMs control in a conflict. Within each preference statement, relationships among options are stated using first order logic. For example, in a given conflict the DM may most prefer that options numbered as 9 and 10 be taken if the third option is not selected. Based on the ranked preference statements given in terms of option choices, a simple algorithm ranks the states from most to least preferred in which ties can occur. Another method for ordering states is to employ direct specification based on information found in the published literature, and possibly also interviews. The direct specification approach is used in this paper.

$\hat{S}^1$ covers all possible scenarios (real and fictitious) of a real-life dispute. The analysis of a first-level hypergame starts by analyzing each DM's subjective game by using the standard GMCR solution concepts as defined within the paradigm of the first-level hypergame in graph form (Aljefri et al. 2018a). The objective is to obtain the set of equilibrium states in each DM's subjective game. Then, one identifies each DM's strategies embedded in its equilibrium states within its subjective game. After that, one takes the Cartesian product of all the DMs' equilibrium strategies within their subjective games to ascertain the first-level hypergame equilibria. Finally, the set of the first-level hypergame equilibria is classified into eight categories—steady hyper equilibrium (SH), unsteady hyper equilibrium (UH), stealthy hyper equilibrium (STH), unsteady stealthy hyper equilibrium (USTH), contingent hyper equilibrium (CH), unsteady contingent hyper (UCH) equilibrium, self-contingent hyper equilibrium (SCH), and emergent hyper equilibrium (EH) states—to provide strategic insights about the first-level hypergame situation (Aljefri et al. 2018a). The paradigm of a second-level hypergame in graph form is reviewed next.

3.3 Second-Level Hypergame in Graph Form

A second-level hypergame with more than two DMs in graph form consists of a collection of subjective first-level hypergames, each of which represents a particular DM's understanding of the conflict situation (Aljefri et al. 2017). Mathematically, the second-level hypergame with n-DMs in graph form is defined as follows:

$$H^2 = \left\langle H_i^1 ; i \in N \right\rangle \tag{4}$$

DM i's subjective first-level hypergame, $H_i^1 = \langle G_{ji} : j \in N_i \rangle$, consists of a system of subjective games, each of which depicts a particular DM's viewpoint of the conflict

situation as perceived by *DM i*. Mathematically, *DM j's* subjective game as perceived by *DM i* is defined as follows.

$$G_{ji} = \left\langle N_{ji}, S_{ji}, \left\{A_{kji} : k \in N_{ji}, j \in N_i\right\}, \ \left\{\succsim_{kji} : k \in N_{ji}, j \in N_i\right\}\right\rangle \tag{5}$$

The elements of G_{ji} are: N_{ji} is the set of DMs perceived by *DM j* and then by *DM i*; S_{ji} is the set of feasible states as perceived by *DM j* in its subjective game and then interpreted by *DM i*; A_{kji} denotes the possible state transitions for *DM k* from one state to another in S_{ji} as perceived by *DM j* and then by *DM i*; and $\succsim_{kji}$ symbolizes *DM k's* preferences over the state space S_{ji} as perceived by *DM j* and then *DM i*.

The analysis of a second-level hypergame is conducted in two phases: (1) the analysis of each DM's subjective first-level hypergame and (2) the overall second-level hypergame analysis. For $i \in N$, *DM i's* subjective first-level hypergame H_i^1 is investigated as follows:

1. For each $j \in N_i - \{i\}$, analyze G_{ji} as a regular game utilizing GMCR's solution concepts to ascertain the equilibria in G_{ji}.
2. For each $j \in N_i - \{i\}$, identify *DM j's* winning strategies out of its equilibrium states in G_{ji}.
3. For all DMs in $N_i - \{i\}$, calculate the Cartesian product of all DMs' winning strategies obtained from step 2 above.
4. Now, in G_{ii}, calculate the stability of states for *DM i* using the standard GMCR solution concepts defined within the second-level hypergame methodology in graph form. If (a) a state in G_{ii} is stable for *DM i* under a specific stability definition and (b) the opponents' strategies related to this particular state belong to the set of strategies identified in step 3 under the same stability definition, the state is an equilibrium in G_{ii} under this solution concept. Note that if a state is an equilibrium in G_{ii}, it is also an equilibrium in H_i^1.

In Phase 2, the overall second-level hypergame is ascertained by taking the Cartesian product of all DMs' strategies obtained from the equilibrium states in their subjective games within their subjective first-level hypergames. To provide strategic insights about the second-level hypergame situation, the equilibrium states are classified into eight categories as is done for the first-level hypergame (Aljefri et al. 2017).

3.4 *h*-Level Hypergame in Graph Form

Aljefri et al. (2018b) generalized the concepts of the first-level and second-level hypergame in graph form to capture DMs' different levels of viewpoint in a conflict situation. An *h*-level hypergame reflects the circumstance in which players see different games, and the highest level of viewpoint in each DM's subjective game is $h - 1$. Mathematically, an *h*-level hypergame for the case of n-DMs in graph form is defined as follows:

$$H^h = \left\langle H_i^{h-1} : \forall i \in N, \ h = 1, 2, 3, \ldots \right\rangle \tag{6}$$

where H^h is the *h*-level hypergame; $h = \{1, 2, 3, \ldots\}$ and H_i^{h-1} denotes *DM i's* $(h - 1)$ *level* subjective game.

As explained earlier, hypergame theory in graph form can be used to investigate a diverse range of real-life conflicts under different levels of perception. For instance, the negotiations among the Eastern Nile countries in early January 2014 and late August 2014 are modeled and analyzed within the architecture of a zero-level hypergame in graph form, as the parties shared a common perception about the conflict situation and were aware of each other's parameters. However, the Eastern Nile countries' dispute just before April 11, 2011 is modeled and analyzed using the paradigm of a second-level hypergame in graph form, since one of the DMs was aware of the other DMs' misperceptions. This dispute is now formally studied in the next section.

4 The Conflict Just Before April 11, 2011

The Eastern Nile countries' conflicts over the construction of GERD took a critical turn when Ethiopia publicly announced on April 11, 2011 its decision to build GERD on the Blue Nile River without giving the downstream nations Egypt and Sudan, any prior notification, and without gaining their approval (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016). GERD includes a reservoir that is estimated to hold up to 70 BCM of water, and a power generation capacity of 6000 megawatts. As such, it is the largest hydraulic dam in Africa in terms of power generation capacity. Ethiopia tendered the construction of the dam to an Italian company at a total cost of US $4.7 billion and the project is expected to be completed in 2017. As of 2016, 70% of the dam construction was completed (International Rivers 2014; Abbas 2016; Ministry of Water, Irrigation, and Electricity 2016; Wheeler et al. 2016). The primary purpose of the dam is claimed to be hydroelectricity generation. Ethiopia secured the financing of the project locally by issuing diaspora bonds (Davison 2011). International investors were not motivated to fund the project with the Ethiopian government due to Egypt's strong opposition to any projects on the Blue or White Nile.

To avoid any direct and severe confrontation with Egypt, Ethiopia released its decision to commence construction of GERD in the middle of the Egyptian revolution, which commenced on January 25, 2011 (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016). Although Ethiopia was adamant that it will implement the project, with or without cooperation from Egypt and Sudan, the speech delivered by the then Prime Minister of Ethiopia, Meles Zenawi, on April 11, 2011, emphasized that Egypt and Sudan would benefit from the dam; and, as a result, invited them to co-fund it.

Both Egypt and Sudan expressed their mistrust and rejection of GERD. Egypt received the news of Ethiopia's unilateral decision to construct GERD while in the midst of a critical political situation. As a result, significant courses of action such as political retaliation were not considered. Instead, Egypt emphasized its historical water rights that had been granted to it by the 1929 agreement and later by the 1959 accord (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016). Moreover, Egypt declared that GERD would reduce the volume of water flow from the Blue Nile River to the Nile River in Egypt, would reduce the hydroelectric capacity of AHD, and would turn some of Egypt's irrigated fields into desert.

Hence, Egypt demanded that all research on GERD be provided so that the negative implications of GERD on Egypt could be accurately assessed. It is worth noting that the same concerns were raised by Egypt when, in 2008, the JMP of the Eastern Nile countries proposed constructing a dam in the Ethiopian highlands within the Blue Nile River (Ramadan et al. 2013; Arjoon et al. 2014; Whittington et al. 2014; Cascão and Alan 2016).

Sudan also rejected Ethiopia's decision to start building GERD. The construction safety of GERD was of prominent concern to Sudan as any breaking, slipping, or collapsing of the dam would topple and destroy many Sudanese villages and cities, including the capital city of Khartoum (Arjoon et al. 2014; Whittington et al. 2014; Cascão and Alan 2016). Despite its strong opposition in 2011, Sudan had supported the construction of the dam in the Ethiopian highlands within the Blue Nile River in 2008, when such a dam was proposed by JMP of the Eastern Nile countries. Sudan backed JMP's proposal due to its overwhelming desire to obtain additional water for its ambitious irrigation and agriculture projects that would enhance the state growth plan.

The Eastern Nile countries' dispute over GERD encountered a special type of misperception. In particular, Egypt and Sudan were unaware of Ethiopia's intention to commence GERD as announced on April 11, 2011 without any prior notification or approval, while Ethiopia, on the other hand, was aware of Egypt and Sudan's misperception (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016). Therefore, the structure of the second-level hypergame in graph form (SLHG) (Aljefri et al. 2017) is used to model and analyze the conflict just before April 11, 2011. The modeling of the universal set of states for a second-level hypergame is first addressed.

4.1 Modeling the Universal Set of States for a Second-Level Hypergame

The DMs and their courses of action for the hydropolitical conflict just before April 11, 2011 are given in Table 1. Note that three DMs are participating in the dispute over GERD: Egypt (denoted by EGY), Sudan (denoted by SU), and Ethiopia (denoted by ETH). As can be seen, Egypt has two options: (1) maintain the status quo by adhering to the 1959 agreement or (2) agree to implement a cooperative hydraulic project within JMP of the Eastern Nile countries. Sudan, on the other hand, has the same two options as Egypt. Ethiopia, which is the only upstream country in this dispute, has three options: (1) obey the 1959 agreement, (2) implement a cooperative hydraulic project with the Eastern Nile countries within the framework of JMP, or (3) implement an independent national hydraulic project. In this conflict, Egypt and Sudan were unaware of Ethiopia's intention to construct the dam on the Blue Nile River, while Ethiopia was aware of this misperception on Egypt and Sudan's part. Hence, Ethiopia's option to act independently and start building a hydroelectric dam on the Blue Nile River was hidden from both Egypt and Sudan and will not be considered in their subjective games (Aljefri et al. 2017, 2018a).

The options in Table 1 are used to mathematically define the universal set of states for a second-level hypergame, $\hat{S}^2$. Since a DM can decide to select an option or not,

Table 1 DMs and options in the hydropolitical conflict just before April 11, 2011

DM	Options
Egypt (EGY)	1. Maintain the status quo of the 1959 treaty (Maintain)
	2. Cooperate with hydraulic development (Cooperate)
Sudan (SU)	3. Maintain the status quo of the 1959 treaty (Maintain)
	4. Cooperate with hydraulic development (Cooperate)
Ethiopia (ETH)	5. Obey the 1959 treaty (Obey)
	6. Cooperate with hydraulic development (Cooperate)
	7. Commence independently (Commence)

Table 2 The universal set of states for a second-level hypergame

DM	Option	States																								
EGY	1. Maintain	N	Y	N	N	Y	N	N	Y	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N
	2. Cooperate	N	N	Y	N	N	Y	N	N	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y	N	N	Y
SU	3. Maintain	N	N	N	Y	Y	Y	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N
	4. Cooperate	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y
ETH	5. Obey	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	6. Cooperate	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N
	7. Commence	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Label		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

there are $2^7 = 128$ mathematically possible states for this dispute. Some of the states in $\hat{S}^2$ are infeasible and need to be eliminated. Because Egypt and Sudan cannot maintain the status quo of the 1959 agreement and implement a cooperative hydraulic project within the NBI framework, options 1 and 2 as well as options 3 and 4 are mutually exclusive (Fang et al. 1993; Kilgour and Hipel 2005). The states in which Egypt and/or Sudan choose these options together are removed from the model. This constraint removes 56 states. Furthermore, Ethiopia cannot obey the 1959 agreement, implement a cooperative hydraulic project, and commence an independent national project together since they are mutually exclusive. Thus, this removes 18 states further. Moreover, the situation in which Ethiopia takes no action is highly unlikely to ever be taken, the states containing this combination of options are infeasible, thus removing 9 more states. Finally, the circumstance in which Egypt and Sudan cooperate and Ethiopia obeys the 1959 agreement is infeasible, which removes one additional state. Hence, for the dispute just before April 11, 2011, 26 states were found to be feasible as shown in Table 2.

Each option or course of action in Table 2 is marked with a number and can be either chosen (Y for yes) or not (N for no) by the DM who controls it. Each state in Table 2 accounts for a possible real-life scenario (Howard 1971; Kilgour et al. 1987; Fang et al. 1993; Kilgour and Hipel 2005). These states are then used to formulate states in each DM's subjective first-level hypergame (Aljefri et al. 2017, 2018a). State 13 is the status quo for the conflict, the state in which the conflict started just before April 11, 2011.

As mentioned earlier, SLHG is a structure consisting of subjective first-level hypergames, each of which represents not only a DM's viewpoint of the conflict situation

but also its opinion on its opponents' subjective games (Aljefri et al. 2017, 2018a). Mathematically, the structure of a second-level hypergame, H^2, for the dispute just before April 11, 2011 is provided as follows:

$$H^2 = \left\{ H^1_{EGY}, H^1_{SU}, H^1_{ETH} \right\} \tag{7}$$

where H^1_{EGY}, H^1_{SU}, and H^1_{ETH} stand for Egypt's, Sudan's, and Ethiopia's subjective first-level hypergames, respectively. In the dispute between Egypt, Sudan, and Ethiopia, it has been noted that Egypt and Sudan share the same misperception about Ethiopia (i.e., unaware of Ethiopia's intention to commence building a dam on the Blue Nile without first reaching an agreement with Egypt and Sudan). Additionally, the investigation reveals that both Egypt and Sudan correctly capture each other's options and preferences in the dispute. These insightful results allow the authors to assume that Egypt's subjective first-level hypergame is identical to Sudan's subjective first-level hypergame (i.e., $H^1_{EGY} = H^1_{SU}$). Therefore, one can analyze H^1_{EGY} only and obtain both of Egypt and Sudan's stable strategies that are associated with the equilibrium states in H^1_{EGY}.

4.2 Stability Analysis and Equilibrium Results for Egypt's and Sudan's Subjective First-Level Hypergame

Egypt's subjective first-level hypergame H^1_{EGY} can be defined as follows.

$$H^1_{EGY} = \{G_{EGY\ EGY}, G_{SU\ EGY}, G_{ETH\ EGY}\} \tag{8}$$

where $G_{EGY\ EGY}$, $G_{SU\ EGY}$, and $G_{ETH\ EGY}$ are Egypt's, Sudan's, and Ethiopia's subjective games, respectively, as seen by Egypt. From Table 2, notice that these 17 states are the ones shown in the left part of the table for which there is an N opposite the option Commence controlled by ETH. Egypt assumes that its subjective game is the actual one for the dispute and all the engaging DMs see it in this manner. That is, $G_{EGY\ EGY} = G_{SU\ EGY} = G_{ETH\ EGY}$. Therefore, one needs to analyze $G_{EGY\ EGY}$ only.

The set of feasible states in $G_{EGY\ EGY}$ is $S_{EGY\ EGY} = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17\}$. Note that some states in the universal set of states $\hat{S}^2$ are unknown to Egypt. The states in which Ethiopia decided to act independently and chose to start building a hydroelectric dam on the Blue Nile River were unknown to Egypt. Therefore, the set of hidden states in Egypt's subjective game is $S^H_{EGY\ EGY} = \{18, 19, 20, 21, 22, 23, 24, 25, 26\}$. Egypt will not consider these states in its subjective game (Aljefri et al. 2017, 2018a).

To conduct a stability analysis in $G_{EGY\ EGY}$, states are put in the order of preference for each DM as perceived by Egypt. DMs' ordinal preferences are given in Table 3 and the reasons for these preferences are explained below. As can be seen in Table 3, states are ranked with respect to each DM from the most preferred state on the left to the least preferred state on the right. Note that DMs' preference information was obtained from an extensive literature review about this challenging conflict.

Table 3 Ranking of states for the DMs in the conflict just before April 11, 2011 as seen by Egypt

DM	States																
Egypt	17	15	11	14	16	9	10	12	13	5	2	4	8	6	3	7	1
Sudan	11	17	15	1	16	5	13	9	2	10	7	8	12	6	3	4	14
Ethiopia	1	4	12	9	7	5	2	13	10	8	6	3	14	11	16	15	17
	Most preferred												Least preferred				

Based on this preference information, an analyst or a modeler can rank the states for each DM, where ties are permitted. Ties or equally preferred states for a given DM are indicated by a bar drawn above or below them. For instance, the horizontal line drawn above states 15 and 11 means that these states are equally preferred by EGY. This technique is the direct specification method mentioned in Sect. 3.2 below Eq. (3). The ranking of states for each DM according to its preferences is discussed below.

1. Based on the direct specification method, state 17 is found to be the most preferred state for Egypt. Recall that the NBI, which was formed in 1999, led, for the first time, Egypt, Ethiopia, and Sudan into finding a mutually beneficial project in the Nile Basin. Hence, state 17 represents the most preferred state for Egypt because it enhances its image in the international community while at the same time maintains its water share from the Nile Basin. In other words, Egypt's highest priority is to cooperate with Sudan and Egypt to explore a mutually beneficial hydraulic project. Hence, one can see from the option form in Table 2 that state 17 is the state in which each of the three DMs select its option to cooperate. In Table 3, notice that state 17 is written on the far left at the top of Table 3 in Egypt's ranking of states. Egypt's second level of preference is to either do nothing or maintain the 1959 agreement while both Sudan and Ethiopia are exploring possible cooperative water development projects. Egypt's third level of preference is to either cooperate or maintain the 1959 agreement, Sudan either cooperates or maintains the 1959 agreement, while Ethiopia is still exploring a possible cooperative water development project (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016).
2. Sudan's first preference is for Egypt and Ethiopia to cooperate (state 11) followed by all three DMs cooperating (state 17) and thereby have a good relationship with both Egypt and Ethiopia. Next, Sudan prefers to boost its economy by establishing a cooperative project with Ethiopia, regardless of its relationship with Egypt (state 15). Then, it would like to maintain a strong relationship with Egypt and act according to Egypt's desire (state 1). The least preferred scenarios for Sudan are for it to maintain the 1959 agreement while both Egypt and Ethiopia are choosing to cooperate with each other regarding jointly exploring a possible hydraulic project (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016). Hence, state 14 is the least preferred state for Sudan and is listed on the far right of Sudan's ordering of states in Table 3.

Table 4 Stability analysis and equilibrium results in $G_{EGY\ EGY}$

States		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
EGY	Nash	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO	YES
	SEQ	NO	YES	NO	NO	YES	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
	GMR	NO	YES	NO	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	NO	YES	NO	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
SU	Nash	YES	YES	YES	NO	YES	YES	NO	NO	NO	NO	YES	NO	NO	NO	YES	YES	NO
	SEQ	YES	YES	YES	NO	YES	YES	YES	NO	YES	YES	YES	NO	YES	NO	YES	YES	YES
	GMR	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	NO	YES	NO	YES	YES	YES
	SMR	YES	YES	YES	NO	YES	YES	YES	YES	NO	NO	YES	NO	YES	NO	YES	YES	YES
ETH	Nash	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	YES
	SEQ	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	YES	NO	NO	NO	NO	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	NO	NO	NO	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	NO	NO	NO	YES
Equilibrium	Nash	/	E	/	/	E	/	/	/	/	/	/	/	/	/	/	/	/
	SEQ	/	E	/	/	E	/	/	/	E	/	/	/	/	/	/	/	E
	GMR	/	E	/	/	E	E	/	E	E	E	/	/	E	/	/	/	E
	SMR	/	E	/	/	E	E	/	E	/	/	/	/	E	/	/	/	E

3. Ethiopia's highest priority is to show good will to both Egypt and Sudan by abiding by the 1959 treaty without any pressure from Egypt and Sudan. This is indicated by listing state 1, given in Table 2 in option form, on the far left in Table 3. Ethiopia's second highest preference is to obey the 1959 treaty if either Egypt or Sudan maintains the 1959 agreement. Ethiopia's third preference is to explore a cooperative hydraulic project with both Egypt and Sudan (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016).

After ordering the states based on each DM's preferences, one can analyze $G_{EGY\ EGY}$ by using the standard GMCR solution concepts (Nash 1950, 1951; Howard 1971; Fraser and Hipel 1979, 1984; Fang et al. 1993; Aljefri et al. 2017, 2018a) to investigate DMs' possible moves and counter moves for the purpose of identifying the subjective equilibria in $G_{EGY\ EGY}$. The decision support system GMCR II (Fang et al. 2003a, b) is used to perform the analysis and predict the equilibrium states for the dispute.

DM's individual stability results and the overall equilibria in $G_{EGY\ EGY}$ are furnished in Table 4. Since states 2 and 5 are stable for all DMs under Nash, SEQ, GMR, and SMR solution concepts, they are Nash, SEQ, GMR, and SMR equilibria for $G_{EGY\ EGY}$. States 2 and 5 are strong equilibria in $G_{EGY\ EGY}$ because they are resolutions within all the solution concepts. States 9 and 17 are also strong resolutions because they constitute states that are equilibria under SEQ and GMR. Moreover, states 6, 8, 10, and 13 are weak equilibrium states for the dispute because they are resolutions under GMR and SMR, in which a DM may have sanctions that are detrimental to itself.

Having identified the equilibrium states, one needs to determine Egypt and Sudan's strategies that are related to the equilibrium states in $G_{EGY\ EGY}$. Normally, one obtains each DM's strategies from the equilibrium states in its subjective game. In this case, Egypt and Sudan's strategies are obtained from $G_{EGY\ EGY}$ because $H^1_{EGY} = H^1_{SU}$.

Egypt's strategy related to states 2, 5, 8, 10, and 13 is $g^2_{EGY} = g^5_{EGY} = g^8_{EGY} = g^{10}_{EGY} = g^{13}_{EGY} = (YN)^T$, its strategy related to states 6 and 17 is $g^6_{EGY} = g^{17}_{EGY} = (NY)^T$, and its strategy related to state 9 is $g^9_{EGY} = (NN)^T$. Hence, one can determine Egypt's set of Nash strategies g^{*Nash}_{EGY} as follows:

– $g_{EGY}^{*Nash} = \{g_{EGY}^{2}, g_{EGY}^{5}\} = \{(YN)^T\}$.

Egypt's sets of SEQ, GMR, and SMR strategies, g_{EGY}^{*SEQ}, g_{EGY}^{*GMR}, and g_{EGY}^{*SMR}, respectively, can be obtained analogously as follows:

– $g_{EGY}^{*SEQ} = \{g_{EGY}^{2}, g_{EGY}^{5}, g_{EGY}^{9}, g_{EGY}^{17}\} = \{(YN)^T, (NN)^T, (NY)^T\}$,
– $g_{EGY}^{*GMR} = \{g_{EGY}^{2}, g_{EGY}^{5}, g_{EGY}^{6}, g_{EGY}^{8}, g_{EGY}^{9}, g_{EGY}^{10}, g_{EGY}^{13}, g_{EGY}^{17}\} = \{(YN)^T, (NY)^T, (NN)^T\}$, and
– $g_{EGY}^{*SMR} = \{g_{EGY}^{2}, g_{EGY}^{5}, g_{EGY}^{6}, g_{EGY}^{8}, g_{EGY}^{13}, g_{EGY}^{17}\} = \{(YN)^T, (NY)^T\}$.

Sudan's strategy related to states 2, 9, and 10 is $g_{SU}^{2} = g_{SU}^{9} = g_{SU}^{10} = (NN)^T$, its strategy connected to states 5, 6, and 13 is $g_{SU}^{5} = g_{SU}^{6} = g_{SU}^{13} = (YN)^T$, and its strategy related to states 8 and 17 is $g_{SU}^{8} = g_{SU}^{17} = (NY)^T$. Sudan's sets of Nash, SEQ, GMR, and SMR strategies, g_{SU}^{*Nash}, g_{SU}^{*SEQ}, g_{SU}^{*GMR}, and g_{SU}^{*SMR}, respectively, can be obtained as follows:

– $g_{SU}^{*Nash} = \{g_{SU}^{2}, g_{SU}^{5}\} = \{(NN)^T, (YN)^T\}$.
– $g_{SU}^{*SEQ} = \{g_{SU}^{2}, g_{SU}^{5}, g_{SU}^{9}, g_{SU}^{17}\} = \{(NN)^T, (YN)^T, (NY)^T\}$,
– $g_{SU}^{*GMR} = \{g_{SU}^{2}, g_{SU}^{5}, g_{SU}^{6}, g_{SU}^{8}, g_{SU}^{9}, g_{SU}^{10}, g_{SU}^{13}, g_{SU}^{17}\} = \{(NN)^T, (YN)^T, (NY)^T\}$, and
– $g_{SU}^{*SMR} = \{g_{SU}^{2}, g_{SU}^{5}, g_{SU}^{6}, g_{SU}^{8}, g_{SU}^{13}, g_{SU}^{17}\} = \{(NN)^T, (YN)^T, (NY)^T\}$.

4.3 Stability Analysis and Equilibrium Results for Ethiopia's First-Level Hypergame

Ethiopia's subjective first-level hypergame H_{ETH}^{1} is defined as follows:

$$H_{ETH}^{1} = \{G_{EGY\ ETH}, G_{SU\ ETH}, G_{ETH\ ETH}\} \tag{9}$$

where $G_{EGY\ ETH}$, $G_{SU\ ETH}$, and $G_{ETH\ ETH}$ are Egypt's, Sudan's, and Ethiopia's subjective games, respectively, as seen by Ethiopia.

Ethiopia correctly perceived the conflict situation and was aware not only of its own subjective game but also those of Egypt and Sudan. Ethiopia knows that Egypt and Sudan play the same game and have the same misperception about Ethiopia. Accordingly, in this dispute, Ethiopia utilized this extra insight to its benefit. Also, Ethiopia knows that $G_{EGY\ ETH} = G_{SU\ ETH} = G_{EGY\ EGY}$.

Analysis of H_{ETH}^{1} starts by first analyzing $G_{EGY\ ETH}$ by using a range of GMCR solution concepts of human behavior under conflict. That is, the set of equilibrium states in $G_{EGY\ ETH}$ is calculated and DMs' strategies that are associated with the equilbrium states are determined. Second, in $G_{ETH\ ETH}$, one identifies the states associated with Egypt's and Sudan's strategies arising from the equilibrium states in $G_{EGY\ ETH}$. If a state is stable for Ethiopia according to the particular solution concept in $G_{ETH\ ETH}$, it constitutes an equilibrium in $G_{ETH\ ETH}$. These equilibrium states also comprise resolutions for H_{ETH}^{1} (Aljefri et al. 2017, 2018a). Note that the equilibrium states in $G_{EGY\ EGY}$ and Egypt's and Sudan's strategies related to the equilibrium states in $G_{EGY\ EGY}$ are the same for $G_{EGY\ ETH}$ and $G_{SU\ ETH}$. Hence, one only needs to model and analyze Ethiopia's subjective game $G_{ETH\ ETH}$.

Table 5 Ranking of states for the DMs in the conflict just before April 11, 2011 as seen by Ethiopia

DM	States																									
Egypt	17	15	11	14	16	9	10	12	13	5	2	4	8	6	3	7	1									
Sudan	11	17	15	1	16	5	13	9	2	10	7	8	12	6	3	4	14									
Ethiopia	18	22	19	21	23	25	20	24	26	17	15	11	14	16	9	10	12	13	5	2	4	6	3	7	1	8
	Most preferred																						Least preferred			

The modeling of $G_{ETH\ ETH}$ starts by identifying the set of feasible states as perceived by Ethiopia in its subjective game, denoted by $S_{ETH\ ETH}$. Because Ethiopia correctly captured the conflict situation, it perceived all the states in $\hat{S}^2$. Hence, $S_{ETH\ ETH} = \hat{S}^2 = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26\}$. However, based on Ethiopia's perception, $S_{ETH\ ETH}$ is partitioned into two disjoint sets: the group of states that are correctly perceived by Ethiopia as well as Egypt and Sudan (Aljefri et al. 2017, 2018a), denoted as $S^R = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17\}$; and the collection of states that are correctly perceived by only Ethiopia and hidden to Egypt and Sudan, expressed as $S^P_{ETH\ ETH} = \{18, 19, 20, 21, 22, 23, 24, 25, 26\}$ (Aljefri et al. 2017, 2018a).

Egypt's and Sudan's preferences as perceived by Ethiopia are identical to their preference in $G_{EGY\ EGY}$. Ethiopia's preferences as perceived by itself are explained as follows (Blackmore and Whittington 2008; Cascão 2012; Salman 2013; Cascão and Alan 2016). Ethiopia's first preferences are to implement an independent water development project on the Blue Nile River. Of course, Ethiopia wishes to do so as Egypt and Sudan decide to take no action. However, Ethiopia is adamant about building a dam on the Blue Nile River and, as a result, would also prefer to pursue its water development even if Egypt and Sudan maintain the 1959 agreement. The second preferences for Ethiopia are to cooperate with Egypt and Sudan regarding building a mutually beneficial water development project on the Blue Nile River, whereas the least favored situations for Ethiopia are to obey the 1959 agreement. Maintaining the status quo means that Ethiopia cannot build a dam on the Blue Nile River and continues to have an unfair share of the Blue Nile River water.

Table 5 shows the ranking of states from most to least preferred for Egypt, Sudan, and Ethiopia as perceived by Ethiopia in $G_{ETH\ ETH}$. Because Ethiopia correctly understands the conflict situation and was also aware of Egypt's and Sudan's misperception, Egypt's and Sudan's preference relationships in Table 5 are identical to their preference relationships as presented in Table 3.

To identify the equilibria in $G_{ETH\ ETH}$, the group of states that are related to Egypt's and Sudan's winning strategies obtained from the equilibrium states in Table 4 needs to be checked for stability. Note that all the states in $S_{ETH\ ETH}$ are related to Egypt's and Sudan's winning strategies. Therefore, Ethiopia's individual stability analysis needs to be carried out over all the states in $S_{ETH\ ETH}$. The results of Ethiopia's individual stability analysis and equilibrium results in $G_{ETH\ ETH}$ are presented in Table 6.

As can be seen in Table 6, states 18, 19, 20, 21, 22, 23, 24, 25, and 26 are Nash stable for Ethiopia as no unilateral improvements (UIs) are available for Ethiopia, beginning

Table 6 Ethiopia's individual stability analysis and equilibrium results in $G_{ETH\ ETH}$

States		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
EGY	g^{*Nash}	YES	NO	NO	NO	YES	NO	NO	YES	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO	YES	NO
	g^{*SEQ}	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
	g^{*GMR}	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
	g^{*SMR}	YES	YES	YES	NO	YES	YES	NO	YES	NO	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	NO	YES	YES	YES	YES	YES
SU	g^{*Nash}	YES	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES	YES	YES	YES	NO	NO	NO	YES	YES	YES	YES	YES	YES	NO	NO	NO
	g^{*SEQ}	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
	g^{*GMR}	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
	g^{*SMR}	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
ETH	Nash	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES
	SEQ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES
	GMR	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES
Equilibrium	Nash	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	E	/	/	E	/	/	/	/
	SEQ	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	E	E	E	E	E	E	E	E	E
	GMR	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	E	E	E	E	E	E	E	E	E
	SMR	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	E	E	/	E	E	E	E	E

from these states and moving to any other more preferred states. These states are also stable under SEQ, GMR, and SMR by definition (Nash 1950, 1951; Howard 1971; Fraser and Hipel 1979, 1984; Fang et al. 1993; Aljefri et al. 2017, 2018a). The other states are unstable for Ethiopia because there is at least a UI from them from which Egypt and Sudan have no deterrent sanctioning moves. For example, Ethiopia can move from state 12 to a more preferred state 21. Egypt and Sudan are not aware of state 21; as a result, they have no credible deterrent. Therefore, Ethiopia will take advantage of Egypt and Sudan's misperception and move to state 21.

As mentioned earlier, if a state that is individually stable for Ethiopia in $G_{ETH\ ETH}$ under a particular solution concept and Egypt's and Sudan's strategies related to that state are found to be stable under the same stability definition in $G_{EGY\ ETH}$, then the state is considered as an equilibrium in $G_{ETH\ ETH}$ within that specific solution concept.

For example, states 19 and 22 are individually stable for Ethiopia in $G_{ETH\ ETH}$ under Nash, SEQ, GMR, and SMR solution concepts. Also, Egypt's and Sudan's strategies related to states 19 and 22 are found to be stable in $G_{EGY\ ETH}$ under all the solution concepts. Thus, states 19 and 22 are Nash, SEQ, GMR, and SMR equilibria in $G_{ETH\ ETH}$. Furthermore, by investigating the data in Table 6 one can see that states 18 and 21 are SEQ and GMR equilibria in $G_{ETH\ ETH}$. Additionally, states 20, 23, 24, 25, and 26 are SEQ, GMR, and SMR equilibria in $G_{ETH\ ETH}$. Keep in mind that $G_{EGY\ ETH} = G_{EGY\ EGY}$.

Having identified the equilibria in $G_{ETH\ ETH}$, one needs to determine Ethiopia's strategies that are associated with these equilibrium states. Ethiopia's strategy related to states 18, 19, 20, 21, 22, 23, 24, 25, and 26 is $g^{18}_{ETH} = g^{19}_{ETH} = g^{20}_{ETH} = g^{21}_{ETH} = g^{22}_{ETH} = g^{23}_{ETH} = g^{24}_{ETH} = g^{25}_{ETH} = g^{26}_{ETH} = (NNY)^T$. Ethiopia's sets of Nash, SEQ, GMR, and SMR strategies are defined as $g^{*Nash}_{ETH} = g^{*SEQ}_{ETH} = g^{*GMR}_{ETH} = g^{*SMR}_{ETH} = \{g^{18}_{ETH}, g^{19}_{ETH}, g^{20}_{ETH}, g^{21}_{ETH}, g^{22}_{ETH}, g^{23}_{ETH}, g^{24}_{ETH}, g^{25}_{ETH}, g^{26}_{ETH}\} = \{(NNY)^T\}$. In the next section, the stability analysis and equilibrium results for the second-level hypergame are put forward.

4.4 Stability Analysis and Equilibrium Results for the Second-Level Hypergame Just Before April 11, 2011

Higher level strategic insights can be garnered for this GERD dispute by ascertaining stability results for the second-level hypergame. Specifically, the overall equilibria for a second-level hypergame can be determined by taking the Cartesian product of Egypt's and Sudan's strategies that are related to the equilibrium states in $G_{EGY\ EGY}$ within H^1_{EGY} with Ethiopia's strategies that are associated with the equilibrium states in $G_{ETH\ ETH}$ within H^1_{ETH}. The results are furnished in Table 7. As can be seen, states 18, 19, 20, 21, 22, 23, 24, 25, and 26 are found to be possible equilibrium states for the second-level hypergame. States 19 and 22 are Nash, SEQ, GMR, and SMR equilibria for the second-level hypergame because Egypt's, Sudan's, and Ethiopia's strategies linked with states 19 and 22 are stable under the same solution concepts. These two states are the strongest resolutions to the dispute because they are resolutions under all four of the solution concepts. Further, states 20, 23, 25, and 26 are equilibria under SEQ, GMR, and SMR solution concepts for the conflict. Finally, states 18, 21, and

Table 7 Equilibrium results for the second-level hypergame

EGY	Winning Strategy									
	Stability	YN	YN	YN	NN	NN	NN	NY	NY	NY
	Nash	YES	YES	YES	NO	NO	NO	NO	NO	NO
	SEQ	YES	YES	YES	YES	YES	YES	YES	YES	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	NO	NO	NO	YES	YES	YES
SU	Winning Strategy									
	Stability	NN	YN	NY	NN	YN	NY	NN	YN	NY
	Nash	YES	YES	NO	YES	YES	NO	YES	YES	NO
	SEQ	YES	YES	YES	YES	YES	YES	YES	YES	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES	YES
ETH	Winning Strategy									
	Stability	NNY	NNY	NNY	NNY	NNY	NNY	NNY	NNY	NNY
	Nash	YES	YES	YES	YES	YES	YES	YES	YES	YES
	SEQ	YES	YES	YES	YES	YES	YES	YES	YES	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES	YES
States		19	22	25	18	21	24	20	23	26
Second-Level Hypergame Equilibrium	Nash	HE	HE	/	/	/	/	/	/	/
	SEQ	HE	HE	HE	HE	HE	HE	HE	HE	HE
	GMR	HE	HE	HE	HE	HE	HE	HE	HE	HE
	SMR	HE	HE	HE	/	/	/	HE	HE	HE
Classification of the Second-Level Hypergame Equilibria	Nash	STHNash	STHNash	/	/	/	/	/	/	/
	SEQ	STHSEQ	STHSEQ	STHSEQ	STHSEQ	STHSEQ	STHSEQ	STHSEQ	STHSEQ	STHSEQ
	GMR	STHGMR	STHGMR	STHGMR	STHGMR	STHGMR	STHGMR	STHGMR	STHGMR	STHGMR
	SMR	STHSMR	STHSMR	STHSMR	/	/	/	STHSMR	STHSMR	STHSMR

Table 8 Evolution of the conflict just before April 11, 2011

DM	Option	Status Quo	Equilibrium State
EGY	1. Maintain	Y	Y
	2. Cooperate	N	N
SU	3. Maintain	Y	Y
	4. Cooperate	N	N
ETH	5. Obey	N	N
	6. Cooperate	Y →	N
	7. Commence	N →	Y
Label		13	22

24 are found to be SEQ and GMR equilibria for the dispute because DMs' strategies related to these states are stable under SEQ and GMR solution concepts.

These equilibrium states are classified as steady stealthy hypergame equilibria for a second-level hypergame because they (1) are only recognized by Ethiopia, (2) constitute resolutions in $G_{ETH\ ETH}$, and (3) are unknown states to both Egypt and Sudan (Aljefri et al. 2017, 2018a). A steady stealthy hyper equilibrium state for a second-level hypergame demonstrates the planned use of a strategic surprise by at least one DM in a conflict situation (Aljefri et al. 2017, 2018a).

Historically, state 22, the steady stealthy hyper Nash equilibrium state, comprised the equilibrium of the conflict. State 22 is the situation in which both Egypt and Sudan decide not to cooperate with Ethiopia regarding building a dam on the Blue Nile River and to maintain their historical right, as granted to them by the 1959 treaty. It also represents the circumstance in which Ethiopia violated the agreement and surprisingly announced its decision to build a hydraulic dam within the Blue Nile River in the Ethiopian heights, without any prior notification or approval from Egypt.

The evolution of the conflict just before April 11, 2011 is outlined in Table 8. As can be seen, the actual historical evolution of the dispute began by moving from state 13, the status quo of the dispute, on the left to the final resolution, state 22, on the right. Recall that in 2010 both Egypt and Sudan refused to sign the CFA and emphasized their historical water shares as provided under the 1959 agreement. At the same time, Ethiopia lost hope of developing a hydraulic project within a cooperative framework with Egypt and Sudan. Due to Egypt and Sudan's misperception, state 13 is predicted by them as a possible final resolution of the dispute on April 11, 2011 as can be seen in their games $G_{EGY\ EGY}$ and $G_{SU\ SU}$, respectively, that state 13 is a GMR and SMR equilibrium. Egypt and Sudan underestimated Ethiopia's capability to individually build a dam on the Blue Nile River. As a result, both Egypt and Sudan were faced with a strategic surprise when Ethiopia announced its decision, on April 11, 2011, to construct a massive hydroelectric dam on the Blue Nile River as a national project. Ethiopia was aware of Egypt and Sudan's political instability and announced its decision at a very critical time for both countries. While Egypt received the news

of GERD in the midst of the Egyptian revolution, Sudan became aware of Ethiopia's decision when South Sudan was about to receive its independence from Sudan.

After Egypt and Sudan became aware of their misperception, the intensity of the conflict between the Eastern Nile countries declined. In May 2011, Egypt, Ethiopia, and Sudan agreed to establish an international panel of experts (IPoE) for the purpose of assessing the engineering and construction plans for the dam. The board consisted of 10 experts: two specialists from each country and four international experts. The IPoE was given one year to conduct its study and was required to submit its report to the three countries by May 2013. The possible confrontation between the Eastern Nile countries over the release of the IPoE's report was addressed in the investigation of the negotiation between the Eastern Nile countries during the third tripartite meeting of the ministers of water resources that took place from January 4 to 5, 2014, and will be discussed in the next section (IPoE 2013; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016).

5 The Conflict Just Before January 4, 2014

On May 28, 2013, Ethiopia diverted the natural flow of the Blue Nile River in order to start building the GERD structure. Egypt expressed its disapproval of Ethiopia's actions and asked the country to halt construction until the IPoE's report had been released (Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016). A few days later, on May 31, 2013, the IPoE published its report, which recommended that Ethiopia conduct in-depth studies on the impacts of the GERD project. It also suggested that Ethiopia modify the structural measures of the dam to ensure that its foundation would be stable and safe. Further information about the IPoE's recommendations can be found in IPoE (2013). Egypt and Sudan reacted differently to the release of the IPoE's report.

Sudan, a country that would benefit significantly from the dam, publicly announced its approval of GERD. Sudan supported the construction of GERD for economic but not for political reasons. Therefore, it clearly stated that it would act as a mediator between Egypt and Ethiopia to try to bridge the gap between them (Sudan Tribune 2013, 2014; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016).

Egypt, which from June 24, 2012 to July 2013 was under the leadership of the former president Mohammed Morsi, disputed the validity of the IPoE's report and stressed the water security granted to it by the 1959 agreement (IPoE 2013; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016). The meeting led by the former president Mohammed Morsi in June 2013 recommended deterring Ethiopia from constructing the dam by threatening to use military power there (Ahramonline 2013). However, Ethiopia stressed its good relationships with its neighboring countries and clearly stated that it would not go to war with Egypt over GERD (IPoE 2013; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016).

From November 2013 to January 2014, Egypt, Ethiopia, and Sudan held three tripartite ministerial meetings in the Sudanese capital city of Khartoum. The purpose of the meetings was to negotiate how to implement the IPoE's recommendations. Egypt proposed forming an international expert committee to conduct the studies suggested by the IPoE (Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016). It also sug-

gested halting the construction of GERD until the investigations had been completed. Ethiopia, on the other hand, rejected Egypt's request, stating that the IPoE recommended that Ethiopia have the authority to conduct the studies without suspending the construction of GERD. As a result of the strong disagreement between Egypt and Sudan, the negotiation process between the Eastern Nile countries stopped after the third meeting from January 4 to 5, 2014, yet the construction of GERD continued (Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016).

Before the January 2014 negotiation, DMs are completely aware of each other's options and preferences. Therefore, the structure of a zero-level hypergame in graph form, H^0 (Aljefri et al. 2018a), which models and analyzes real-life disputes under the assumption of complete information, is utilized to model and analyze the hydropolitical conflict.

5.1 Decision Makers, Options, and States for the Conflict Just Before January 4, 2014

The DMs and courses of actions for the hydropolitical dispute just before January 4, 2014 are given in Table 9. As can be seen, Egypt has three options: (1) accept the IPoE's recommendations, (2) request Ethiopia to modify GERD based on Egypt's recommendations, or (3) require Ethiopia to amend GERD based on Egypt's reduced terms. Sudan, which decided in this dispute to act as a third party, has one single course of action: to act or not. Ethiopia, which is the only upstream country in this dispute, has three options: (1) accept modification of GERD based on the IPoE's recommendations, (2) accept modification of GERD based on Egypt's conditions, or (3) accept modification of GERD based on Egypt's reduced terms. The descriptions of these courses of actions are shown in Table 9.

Each option in Table 9 can be either selected (Y for Yes) or not selected (N for No) by the DM who possesses it. Therefore, the total number of mathematically possible states for this dispute is $2^7 = 128$ states. Some of these states are infeasible and need to be removed from the model. Egypt's options are mutually exclusive since it cannot choose more than one of its three options at a time. This removes 64 states. Similarly, Ethiopia can only modify GERD based on one recommendation. Hence, the situations in which Ethiopia accepts modification of GERD based on more than one recommendation are infeasible. This removes 32 states. Hence, for this dispute, 32 states are found to be feasible as shown in Table 10.

5.2 Stability Analysis and Equilibrium Results for the Dispute Just Before January 4, 2014

To conduct a stability analysis for H^0, states are put in order of preference for each DM. The ranking of states from most to least preferred for Egypt, Sudan, and Ethiopia is given in Table 11. Note that a line above or below a group of states means that they are equally preferred. Based on the preference statements below, states are ranked with respect to each DM in this dispute.

Table 9 DMs, options, and descriptions for the conflict just before January 4, 2014

DM	Option	Choice	Description
Egypt	1. Accept the IPoE's recommendations	Y	Allows Ethiopia to proceed with the construction of the GERD based on the IPoE's recommendations
		N	Disputes the validity of the IPoE's report
	2. Request Ethiopia to modify the GERD based on Egypt's recommendations	Y	Demands that Ethiopia halts the construction of GERD and requests an international committee to conducts the studies recommended by the IPoE
		N	The option is not taken
	3. Require Ethiopia to amend the GERD based on Egypt's reduced terms	Y	Permits Ethiopia to continue building the GERD while the international committee conducts the studies
		N	The option is not taken
Sudan	4. Act	Y	Acts as a third party to mediate between Egypt and Ethiopia for reconciliation
		N	Does not act
Ethiopia	5. Accept modifications to the GERD based on the IPoE's recommendations	Y	Proceeds with building the GERD and modifies the project based on the IPoE's requirements
		N	Continues building the GERD based on Ethiopia's original plans
	6. Accept modifications to the GERD based on Egypt's conditions	Y	Stops building the GERD and allows an international committee to conduct the IPoE's recommendations
		N	Continues building the GERD based on Ethiopia's original plans
	7. Accept changing the GERD based on Egypt reduced terms	Y	Continues building the GERD and allows an international committee to conduct the IPoE's recommendations
		N	Continues building the GERD based on Ethiopia's original plans

1. Egypt first preference is to request Ethiopia to stop construction of GERD and to modify it based on Egypt's requirements. Next, Egypt prefers that Ethiopia modify GERD based on its reduced terms. These terms would allow Ethiopia to continue building GERD until the international committee had completed its studies. After that, Egypt prefers that Ethiopia modify GERD based on the IPoE's recommendations. The least preferred scenarios for Egypt are when it does nothing and Ethiopia continues building GERD based on Ethiopia's original plans.
2. Sudan prefers, first, to act as a third party to facilitate a deal between Egypt and Sudan. Sudan's second preferences are not to interfere as long as Egypt and Ethiopia continue to negotiate a resolution to GERD. The least preferred scenarios for Sudan are when it decides not to act and both Egypt and Ethiopia halt the negotiation process.

Table 10 Set of feasible states for the conflict just before January 4, 2014

DM	Option	States																															
EGY	1. IPoE's Terms	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N
	2. EGY's Terms	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N
	3. EGY's Reduced Terms	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y	N	N	N	Y
SU	4. Act	N	N	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y
ETH	5. Accept IPoE Terms	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	6. Accept EGY Terms	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
	7. Accept EGY Reduced Terms	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

Table 11 Ranking of states for the DMs in the conflict just before January 4, 2014

DM	States																															
Egypt	23	19	31	27	24	20	22	18	21	17	32	28	30	26	29	25	15	11	16	12	14	10	13	9	3	7	8	4	6	2	5	1
Sudan	14	15	16	22	23	24	30	31	32	10	11	12	18	19	20	26	27	28	6	7	8	13	21	29	2	3	4	9	17	25	5	1
Ethiopia	14	10	13	9	16	12	15	11	1	5	2	6	8	4	7	3	32	28	31	27	30	26	29	25	23	19	24	20	22	18	21	17
	Most preferred																														Least preferred	

Table 12 Stability analysis and equilibrium results for the negotiation in January 2014

States		9	10	11	12	13	14	15	16
EGY	Nash	NO	NO	YES	NO	NO	NO	YES	NO
	SEQ	NO	NO	YES	NO	NO	NO	YES	NO
	GMR	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES
SU	Nash	NO	NO	NO	NO	YES	YES	YES	YES
	SEQ	NO	NO	NO	NO	YES	YES	YES	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES
ETH	Nash	YES	YES	YES	YES	YES	YES	YES	YES
	SEQ	YES	YES	YES	YES	YES	YES	YES	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES
Equilibrium	Nash	\	\	\	\	\	\	E	\
	SEQ	\	\	\	\	\	\	E	\
	GMR	E	E	E	E	E	E	E	E
	SMR	E	E	E	E	E	E	E	E

3. Ethiopia's first preference is to modify the construction of GERD based on the IPoE's recommendations; its second, to continue with construction of GERD based on its original plans; and its third, to modify GERD founded on Egypt's reduced terms. The least preferred scenarios for Ethiopia are when it modifies GERD based on Egypt's original terms. That means, Ethiopia halts construction of the dam and allows an international committee to conduct the studies recommended by the IPoE's report.

After ordering the states based on each DM's preferences, one can analyze H^0 using the standard GMCR solution concept. GMCR II (Fang et al. 2003a, b) is used to perform the analysis and predict the equilibria for the dispute. The results are shown in Table 12. As can be seen, state 15 comprises the strong equilibrium for the conflict because it is a resolution under Nash, SEQ, GMR, and SMR. States 9, 10, 11, 12, 13, 14, and 16 are weak equilibria for the dispute because they comprise resolutions under GMR and SMR.

Historically, state 15 comprised the equilibrium of the conflict. State 15 is the situation in which Egypt request Ethiopia to stop GERD and form an international committee of experts to conduct in-depth studies about the GERD construction safety. It also represent the situation in which Ethiopia rejects Egypt's demand and continues

Table 13 Evolution of the conflict just before January 4, 2014

DM	Option	Status Quo	Transitional State I	Transitional State II	Equilibrium
EGY	1. IPoE's Terms	N	N	N	N
	2. EGY's Terms	N →	Y	Y	Y
	3. EGY's Reduced Terms	N	N	N	N
SU	4. Act	N	N →	Y	Y
ETH	5. Accept IPoE's Terms	N	N	N →	Y
	6. Accept EGY's Terms	N	N	N	N
	7. Accept EGY's Reduced Terms	N	N	N	N
Label		1	3	7	15

building GERD taking into account the original IPoE's recommendations. Hence, the negotiation process between Egypt, Sudan, and Ethiopia stops as a result of their failure to achieve an agreement, and Ethiopia continues building GERD based on the IPoE's recommendations. The negotiation process between Egypt, Ethiopia, and Sudan stopped from January 2014 to August 2014 (IPoE 2013; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016).

Examining how a conflict progresses over time can often provide valuable strategic insights. The evolution of the conflict in early January 2014 is outlined in Table 13. As can be seen, the dispute started by moving from state 1, the status quo of the dispute, on the left via a transitional state, state 3, to another transitional state, state 7, to the final resolution, state 15, on the right. Egypt disputed the validity of the IPoE's report and requested Ethiopia to halt construction of GERD, and also form an international committee of experts to conduct in-depth engineering analyses of the dam and its regional implications. To bridge the gap between Ethiopia and Egypt, Sudan acted as a third party to try to find a solution to the problem around the negotiation table. However, after three rounds of fruitless negotiations, Egypt and Ethiopia failed to reach an agreement. As a result, the negotiation process stopped and Ethiopia continued to build GERD based on the IPoE's recommendations. In the next section, one can see how the negotiation process continued after President Abdel Fattah el-Sisi was elected on June 8, 2014 and began handling the case of GERD (IPoE 2013; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016).

6 The Conflict Just Before August 25, 2014

The negotiations between Egypt, Ethiopia, and Sudan resumed after the election of Egyptian President Abdel Fattah el-Sisi on June 8, 2014. In a meeting held in Khartoum on August 25, 2014, the Eastern Nile countries agreed to form an international committee of experts to conduct the studies recommended by the IPoE (IPoE 2013; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016). Furthermore, the three nations nominated experts from their own countries to supervise the international committee's work. In this agreement, Egypt decided to drop its request to stop construction of GERD until the studies had been concluded, and Ethiopia accepted the formation of an international committee to conduct these investigations. This agreement facilitated the signing of a Declaration of Principles (DoP) (Ahramonline 2015)

among the Eastern Nile countries in March 2015. This disclosure provides some general guidelines on how to operate GERD after its construction is completed in 2017. The modeling and analysis of the conflict just before August 25, 2014 is given in this section.

The dispute between the Eastern Nile countries in August 2014 is a continuation of their negotiation that occurred in January 2014 (Matbouli et al. 2013). For two conflicts to be connected, the equilibrium state in the first round must be the status quo for the new round. State 15, the equilibrium state for the dispute that took place on January 4, 2014, was the status quo for the conflict just before August 25, 2014. Therefore, the parameters of the conflict that remained the same are the DMs and their options as shown in Table 9. However, DMs' preferences over the states, in Table 11, are changed because the DMs change their objectives. Their new preference statements are explained below:

- In this dispute, Egypt shows some willingness to cooperate with Ethiopia by dropping its request to stop construction of GERD. Hence, Egypt's first preference is to request Ethiopia to modify GERD based on Egypt's reduced terms; its second, for Ethiopia to modify the project based on its original terms. The least preferred scenarios for Egypt are when it does nothing or requests Ethiopia to modify GERD based on the IPoE's terms, and Ethiopia decides to continue building GERD (IPoE 2013; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016).
- Ethiopia has also shown some eagerness to cooperate with Egypt in this dispute. In particular, it has displayed some willingness to accept Egypt's reduced terms. Therefore, Ethiopia's first preference is to accept modification of the construction of GERD based on Egypt's reduced terms; and second, to modify the building of GERD based on the IPoE's original report. The least preferred scenarios for Ethiopia are when it decides to modify GERD based on Egypt's original conditions (IPoE 2013; Cascão and Alan 2016; Tawfik 2016; Wheeler et al. 2016).
- Sudan continued to act as a third party without any change in its preferences.

Based on the above preference statements, states are ranked from most to least preferred with respect to each DM as shown in Table 14. A range of solution concepts are used to investigate the dispute and predict the possible compromise resolutions for the conflict. For this analysis, a decision support system, GMCR II, was used to perform the calculations. The results are depicted in Table 15. As can be seen, state 32 comprises the strong equilibrium for the conflict because it is a resolution under Nash,

Table 14 Ranking of states for the DMs in the conflict just before August 25, 2014

DM	States																													
Egypt	32	28	30	26	29	25	23	19	31	27	24	20	22	18	21	17	15	11	16	12	14	10	13	9	3	7	8	4	6	2	5	1
Sudan	14	15	16	22	23	24	30	31	32	10	11	12	18	19	20	26	27	28	6	7	8	13	21	29	2	3	4	9	17	25	5	1
Ethiopia	32	28	31	27	30	26	29	25	14	10	13	9	16	12	15	11	1	5	2	6	8	4	7	3	23	19	24	20	22	18	21	17
	Most preferred																										Least preferred					

Table 15 Stability analysis and equilibrium results for the negotiation on August 25, 2014

States		25	26	27	28	29	30	31	32
EGY	Nash	NO	NO	NO	YES	NO	NO	NO	YES
	SEQ	NO	NO	NO	YES	NO	NO	NO	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES
SU	Nash	NO	NO	NO	NO	YES	YES	YES	YES
	SEQ	NO	NO	YES	NO	YES	YES	YES	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES
ETH	Nash	YES	YES	YES	YES	YES	YES	YES	YES
	SEQ	YES	YES	YES	YES	YES	YES	YES	YES
	GMR	YES	YES	YES	YES	YES	YES	YES	YES
	SMR	YES	YES	YES	YES	YES	YES	YES	YES
Equilibrium	Nash	\	\	\	\	\	\	\	E
	SEQ	\	\	\	\	\	\	\	E
	GMR	E	E	E	E	E	E	E	E
	SMR	E	E	E	E	E	E	E	E

Table 16 Evolution of the conflict just before August 25, 2014

DM	Option	Status Quo	Transitional State I	Equilibrium
EGY	1. IPoE's Terms	N	N	N
	2. EGY's Terms	Y	Y →	N
	3. EGY's Reduced Terms	N	N →	Y
SU	4. Act	Y	Y	Y
ETH	5. Accept IPoE's Terms	Y →	N	N
	6. Accept EGY's Terms	N	N	N
	7. Accept EGY's Reduced Terms	N →	Y	Y
Label		15	31	32

SEQ, GMR, and SMR. States 25, 26, 27, 28, 29, 30, and 31 comprise weak equilibria for the dispute because they are resolutions under GMR and SMR.

Historically, state 32 comprised the equilibrium of the conflict. State 32 is the situation in which both Egypt and Ethiopia agree to cooperate, with Egypt requesting Ethiopia to modify GERD based on Egypt's reduced terms to which Ethiopia agrees.

The evolution of the conflict that occurred in August 2014 is outlined in Table 16. As can be seen, the dispute began by moving from state 15, the status quo of the dispute and the equilibrium state for the conflict in early January 2014, on the left, via a transitional state, state 31, to the final resolution, state 32, on the right. The conflict evolved after both Egypt and Ethiopia showed some willingness to cooperate and solve the conflict. Egypt reduced its terms by allowing Ethiopia to continue building GERD simultaneously with the international committee of experts conducting their in-depth studies. Ethiopia, on the other hand, agreed to form an international committee of experts to conduct the studies and continued building GERD. As a result of this understanding between Egypt and Ethiopia, the Eastern Nile countries signed the DoP in March 2015.

Table 17 Overall evolution of the Eastern Nile countries' dispute from April 11, 2011 to August 25, 2014

DM	Option	Just Before April 11, 2011	Just Before January 4, 2014	Just Before August 25, 2014
EGY	1. Maintain the 1959 Treaty	Y	N	N
	2. Cooperate	N	N	N
	3. IPoE's Terms	N	N	N
	4. EGY's Terms	N	Y	N
	5. EGY's Reduced Terms	N	N	Y
SU	6. Maintain the 1959 Treaty	Y	N	N
	7. Cooperate	N	N	N
	8. Act	N	Y	Y
ETH	9. Obey the 1959 Treaty	N	N	N
	10. Cooperate	N	N	N
	11. Commence Independent	Y	Y	Y
	12. Accept the IPoE's Terms	N	Y	N
	13. Accept EGY's Terms	N	N	N
	14. Accept EGY's Reduced Terms	N	N	Y

7 Evolution of the Conflicts and Strategic Insights

The overall evolution of the Eastern Nile countries' disputes over GERD is depicted in Table 17. As can be seen, the conflict over the Nile River water intensified when Ethiopia publicly announced, on April 11, 2011, the beginning of construction of GERD on the Blue Nile River without giving Egypt and Sudan prior notification. Egypt and Sudan were not aware of Ethiopia's intention to build GERD independently; as a result, they encountered a strategic surprise in the dispute. However, after both Egypt and Sudan became aware of their misperception, they expressed their rejection of Ethiopia's decision and requested Ethiopia to respect their respective historic water rights that had been granted to them by the 1959 agreement. Egypt and Sudan took no aggressive deterrent actions to halt Ethiopia from continuing construction of GERD. Instead, they agreed with Ethiopia to form the IPoE for the purpose of studying the adverse impacts of GERD on Egypt and Sudan. The three countries agreed to give the IPoE one year to conduct its analysis and also permitted Ethiopia to continue building GERD. However, after the release of the IPoE report in May 2013, Egypt disputed the validity of the report and requested Ethiopia to stop construction of GERD. Furthermore, Egypt asked for an international committee of experts to conduct an in-depth analysis regarding the negative impacts of the dam. Because Egypt and Ethiopia could not reach an agreement, the negotiations between them stopped, but the construction of GERD continued as shown in the second column in Table 17. The situation improved during the negotiation on August 25, 2014 when Egypt and Ethiopia agreed to form an international committee of experts to conduct some studies on GERD without stopping the construction of the dam. This scenario is depicted in the far right column of Table 17. This agreement facilitated the signing of the DoP in March 2015.

The analysis of the hydropolitical conflict between the Eastern Nile countries over GERD provided the following insights. Firstly, river agreements that allocate unfair allotment among riparian states may create conflict (Tir and Stinnett 2011). Recall that, in 2010, Egypt and Sudan refused to sign the CAF due to the possible implications of this agreement on the volume of water each country would receive from the Nile River. Although a strategic insight such as this one may appear to be obvious, a formal

GMCR investigation clearly explains why this is so and confirms that this is the case. Secondly, powerful nations, militarily, economically, and politically, may influence the negotiations process according to their own interests (Priscoli and Wolf 2009). Since 1959, Egypt has controlled all of the negotiations regarding the use of the Nile River water in its favor. It has also prevented any upstream countries from conducting any water resources development on the Nile River. Thirdly, geopolitical and economic changes in countries may be the reason for a new era of collaboration. As explained earlier, GERD was a cause of political and economic change in the Eastern Nile countries. These changes meant the GERD project became a reality, and cooperation between Egypt, Ethiopia, and Sudan was the only way to move forward. Because of the tumultuous geopolitical changes in Egypt, the government was not ready to capably address the conflict over GERD. If Egypt wanted to prevent GERD from becoming a reality, it should have stopped the progress of the GERD project at its earlier stages. Ethiopia, on the other hand, utilized Egypt's political instability and made significant progress on the construction of GERD. Hence, it became impossible for Egypt to prevent Ethiopia from removing GERD after Ethiopia had already completed more than 60% of the construction as of 2016. The fourth lesson that can be learned from the case presented in this paper is the important role of the utilization of strategic surprise by a DM to achieve better results. The 2011 dispute was modeled as a second-level hypergame because Egypt and Sudan did not anticipate that Ethiopia would start building GERD without prior notification and Ethiopia was aware of Egypt and Sudan's misperception in this respect. The historical equilibrium state for the 2011 dispute, state 22, was predicted under the definition of the stealthy hyper Nash equilibrium state for a second-level hypergame (Aljefri et al. 2017). This definition demonstrates the intended use of strategic surprise by Ethiopia to achieve results in the conflict. This equilibrium is considered to constitute an unstable equilibrium because, as one saw in the analysis of the 2011 conflict, Egypt and Sudan challenged the resolution after they became aware of it. Hence, the conflict between the Eastern Nile countries continued until March 2015.

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